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Sport Fishery and Wildlife Research

1975-76



UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE



UNITED STATES DEPARTMENT OF THE
INTERIOR

CECIL D. ANDRUS, SECRETARY

FISH AND WILDLIFE SERVICE

DIVISIONS OF RESEARCH

As the Nation's principal conservation Agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interests of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

Front cover photo.

Sandwich tern shading young
on Sundown Island, Matagorda Bay, Texas.

Photo by Kirke A. King

Sport Fishery and Wildlife Research

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Activities in the Divisions of Research for
the Fiscal Year 1975-76.

Edited by
Thomas G. Scott, Wildlife
Helen C. Schultz, Wildlife
Paul H. Eschmeyer, Fisheries

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The black-crowned night heron is commonly encountered during investigations of marsh ecology. *Photo by J. T. Lokemoen.*

Foreword

A primary goal of the U.S. Fish and Wildlife Service is the conservation and sound management of sport fishery and wildlife resources for the benefit of present and future generations of Americans. Attainment of this goal requires the continual collection, analysis, and synthesis of new information on which wise and timely management decisions can be based. The Divisions of Research address the principal informational needs of the various management programs of the Service and provide many of the findings that contribute to the accomplishment of the Service's mission.

This summary of the activities of the Research Divisions during the extended fiscal year 1976 (July 1, 1975 — September 30, 1976) provides an overview of the nature and scope of research completed and directs attention to the results that should be of significance in the management of fish and wildlife.

A substantial portion of the research recounted here concerns cooperative studies between Service scientists and those of other Federal agencies, universities, State agencies, and other countries. We thank the many collaborators for their most valued assistance in advancing the Service's diverse research program.



Sport Fishery and Wildlife Research

The research responsibilities of the Fish and Wildlife Service were carried out by four Divisions: Cooperative Research, Cultural Methods Research, Population Ecology Research, and Population Regulation Research. During fiscal year 1976, these Divisions continued to serve as the fact-finding arm of the Service. Information about species of fish and wildlife, the environments required for their existence, and the effects of management practices on them help the U.S. Fish and Wildlife Service and other government agencies to meet their responsibilities for conserving and managing the Nation's fish and wildlife for social, economic, aesthetic, and scientific benefits. In fulfilling the Service's research responsibilities, the Divisions cooperate with agencies of the Departments of Interior, Agriculture, Defense, and Health, Education, and Welfare; the Atomic Energy Commission; the Agency for International Development; the Environmental Protection Agency; and various State agencies, institutions, and private organizations. Completed research is communicated by talks and lectures, processed reports, and articles in popular and technical publications. A list of publications is provided in this report.

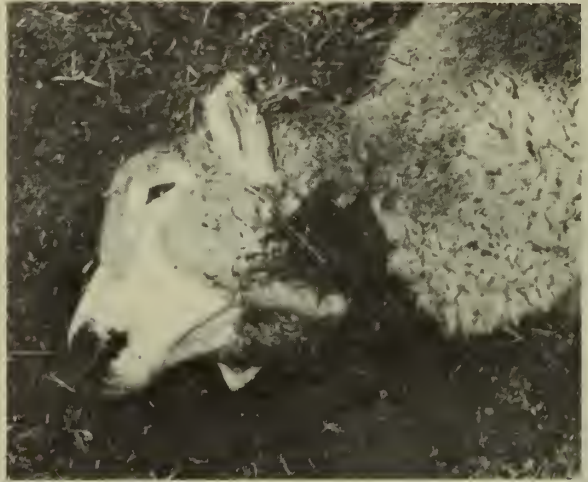
During the fiscal year, research was carried out at 25 major facilities, approximately 60 satellite field stations, and 45 Cooperative Research Units under the following programs: Animal Damage Control, Environmental Contaminant Evaluation, Coastal and Anadromous Fish, Endangered Species, Great Lakes Fisheries, Inland Fisheries and Reservoir Management, Land and Water Resources Development, Migratory Birds, Mammals and Nonmigratory Birds, Biological Services, and Cooperative Units. This alignment of programs permits the application of total agency resources to the attainment of specific objectives and encourages careful priority assessment of ongoing research programs.

The planning, coordination, and administration of the research programs continue to be centralized in the Office of the Associate Director of Environment and Research in Washington, D.C. Fiscal, personnel, and property management and a variety of supporting services are provided the research facilities by the six Regional Offices of the Service. By the end of fiscal year 1976, the Divisions of Research had 730 full-time permanent employees. The budget included approximately \$21,850,000 of appropriated funds and \$3,150,000 of other funds.

Animal Damage Control

DENVER WILDLIFE RESEARCH CENTER

Sheep Losses on Selected Ranches in Southern Wyoming. — To help resolve conflicting claims about the severity of predator losses to the sheep industry, sheep losses from all causes were assessed on five southern Wyoming ranches during 1973-75. About 6,000 ewes and their lambs were monitored each year during spring lambing and the summer and winter grazing seasons. Lambs were much more vulnerable than ewes, and spring losses always exceeded summer and winter losses combined. Of 4,440 dead sheep examined, predators killed 1,030 or 23%. Predation was the largest single cause of death for lambs, but weather-related deaths from starvation, accidents, exposure, and disease, when combined, were greater in number. Most losses of ewes were caused by disease (26%) and predation (18%). During the 3 years, known predator kills were 0.2% of the ewes each year, and 1.5%, 2.1%, and 3.2%, respectively, of the lambs from the study herds. Coyotes caused 77% of the deaths from predation, black bears 11%, and golden eagles 9%. There were 1,232 ewes and lambs missing, mostly during summer, due mainly to miscounting and loose management by one ranch.



Neck wounds indicate that this lamb was killed by a coyote. The toxic collar seeks to exploit the coyote's typical throat attack pattern. Photo by G. E. Connolly.

Losses of Sheep With No Protection from Predators. — Losses of sheep having no protection from predators were investigated on the Cook Ranch, Florence, Montana, March 15, 1974 to March 14, 1976. Coyote predation proved to be the primary cause of sheep losses, and predators killed more than 16% of the flock each year for a total of



A pair of coyotes attacking an adult ewe. Photo by G. E. Connolly.



Coyote damage assessment studies to determine causes and time of sheep losses were conducted in several states. Photo by S. B. Linhart.



Coyote attractants are being evaluated by exposing them in small, plastic capsules and reading "sign" left at the "scent stations." Photo by F. J. Turkowski.



Biologist examines coyote tracks at a scent station in Idaho. A new, synthetic scent developed by Denver Research Center chemists was used for the 5th annual survey of relative predator abundance in September 1976. Photo by G. E. Connolly.

1,027 sheep. Cause of death was undetermined for 0.6% of the known losses the first year and for 0.8% the second year. Coyotes were responsible for 97.1% of the losses to predators the first year (first study) and 99.3% the second year. During the second year, 80.7% of the sheep taken by coyotes were killed by neck and throat wounds. Coyotes were sighted 61 times, dogs 3 times, and red foxes 2 times. Of the 602 sheep killed by coyotes during the second year, scavenging birds fed so extensively on 83 carcasses that the amount of feeding by coyotes could not be determined. Feeding was light to moderate on 401 of the other 519 carcasses, and return feeding was insignificant. Ewe lambs and twins were taken by coyotes more often than wethers and single lambs.

Secondary losses, resulting from harassment by coyotes, included reduced lambing success, increased excitability of flocks, reduced growth rates, difficulty in fattening lambs, and loss of unborn lambs.

Pneumonia, weak calf syndrome, and old age complications were the primary causes of natural deaths. Health of the sheep killed by coyotes was comparable to that of the rest of the herd.

Success in controlling coyotes by M-44's, shooting from a helicopter, snares, experimental sodium cyanide collars, and a spray-on repellent was monitored. Conventional predator control methods killed 44 coyotes: 18 by M-44's, 23 by shooting from a helicopter, and 3 by snares. Three coyotes, radio-collared and tracked during the second year, were seldom found among the sheep. Predation was reduced but not stopped by the conventional controls used.

Annual Survey of Relative Predator Abundance.

— The 1975 annual survey of relative predator abundance in the western United States showed a decline of 5% for coyotes as compared with 1974, at a lowered probability of 80%. The data are intended to reflect year-to-year changes in visitation indices for various predators, particularly coyotes, attracted to standardized scent-station lines. The method was not designed for estimation of numbers of animals per unit area, differences in abundance between species inhabiting the same area, or differences in relative numbers of a single species between areas, although some of these unwarranted interpretations appear in the Press. It is, however, intended to show year-to-year changes in trends, comparing lines sampled one year with those of the previous year.

Analysis of the first 4 years of data (1972-75) indicates that the coyote visitation index for the western United States increased 10% between 1972 and 1973, and again between 1973 and 1974. At a probability level (P) of 95% (5% risk of error), both changes were statistically significant.

No significant changes occurred in the statewide coyote index for any individual state between 1974 and 1975 at the 95% level of probability. Only in North Dakota (decrease of 27%, $P = 85\%$) and in Iowa (increase of 49%, $P = 90\%$) did changes in the visitation rate approach the 95% level of confidence. This lack of significant change may be due to the inherent variability in coyote response and/or insensitivity of the method, which can be compensated for by increasing the number of survey lines or by increasing visitation through the

use of a better attractant.

Most observers consider that the 10% increases (1972, 1973) followed by the 5% decrease (1975) reflect no major impact on coyote populations from control measures, the ban on toxicants, or rising fur prices, unless these factors somehow cancel each other.

The Development of a Synthetic Coyote Attractant and Deer Repellent. — Field tests showing that the volatile components of a fermented egg formulation are attractive to coyotes and repellent to deer suggested that a dual-purpose synthetic mixture could be made from the important compounds in this material. Gas chromatography-mass spectrometry analyses were conducted, and 74 compounds were identified, including acids, alcohols, alkyl aromatics, esters, ketones, and terpenes. These compounds were combined in a stepwise process to form a synthetic mixture that elicited from coyotes and deer behavioral responses similar to those caused by the natural product.

An important aspect of this work was the use of the human nose to eliminate much of the time-consuming and expensive behavioral testing on coyotes and deer. First, compounds were combined according to their relative concentrations in four fermented egg fractions, each of which had a different odor quality (fruity, fishy, sweaty, and sulfurous). The relative concentrations of these compounds were adjusted until the odor closely resembled natural fermented egg. An odor panel of 18 persons (judges) was used for the final refinement of this mixture. Various modifications were compared with the natural product until a blend was achieved that produced a 40% error in discrimination by the judges. This blend was labeled synthetic fermented egg (SFE).

In standardized tests at equivalent odor intensities SFE was statistically equal to the natural fermented egg in attracting coyotes and in repelling deer. The concentration in both cases can be increased over 40-fold. The final stage of development will involve the preparation of formulations of desired longevity and weatherability for field applications.

Predator Attractants Field Tested. — Few of the odor attractants that are used to lure predators to capture devices have been systematically tested for their effectiveness, species selectivity, or the type of response they elicit. Sonic and visual attractants have received only limited attention by researchers. Many attractants have been field tested in an effort to find more efficient and selective techniques for

capturing predators.

Odor attractants were tested by exposing plastic, disk-shaped capsules containing the lures. They were placed at 0.3-mile intervals along primitive ranch roads in random sequence. Predator visits were determined by observing tracks and sign present each day within a cleared area 3 feet in diameter around each capsule. Comparisons of behavioral responses and the numbers of visits to the lures indicated which were most attractive to predators.

Over 3,000 visits by coyotes to odor lures were recorded. Visits of other animals to the lures were also recorded. Data have also been accumulated for other animals. These visitors included raccoons, cattle, bobcats, rabbits, striped skunks, gray foxes, badgers, javelina, and horses. Numbers of visits fluctuated daily, probably because of environmental factors and differences in the behavior of the animals. Strong winds apparently reduced activity and the ability of predators to detect odor sources as there were fewer total visits on the windiest days. Behavior observed included urination, defecation, scratching, digging, biting, licking, pulling, carrying capsules, and rolling on the station.

The results of one test phase indicated that a synthetic egg product was a good attractant — it elicited a high rate of visitation and numerous pulling and biting responses from coyotes. These properties show promise for use with existing operational techniques, and those developed by research. Additional field evaluation is planned.

Ten sonic attractant test devices were constructed and field tested for durability and attractiveness to predators. These units were tested in the same manner as the odor attractants. Each electronic unit was powered by a 9-volt battery and was contained in a 1-pint metal can with a perforated top. When activated, the devices emitted sounds resembling those of prey animals. Five of the devices produced squeaking sounds similar to the distress calls of mice, and the remainder emitted sounds like the warblings of small birds. The warbling devices appeared to attract more predators than the “squeakers.” Wind did not seriously decrease visits to the devices. The units are self-contained, appear weatherproof, and are durable and small enough to be easily transported and camouflaged. If the devices continue to show promise, they will be tested in combination with odor and visual attractants.

Food Storage and Retrieval by Coyotes. — Observations of food storage and retrieval by

penned coyotes near Logan, Utah, are providing information on these basic behavioral patterns. The specific behavior is complex but usually involves transporting the food to the caching site, digging a small depression, dropping the food in the depression, compacting it, and covering it by scraping loose soil, vegetation, or snow over it. The site may or may not be scent-marked by urination. To retrieve caches of food, coyotes carefully scratch away the cover, usually employing one foot at a time. Coyotes give concentrated attention to this task, smelling and watching the hole as they dig. When a portion of the cache becomes visible, the coyote snaps it up in its mouth, shakes it vigorously, and carries it off to eat.

Food storage appears to be triggered by an abundance of food or by difficulties in feeding (e.g., long bones, skulls, or frozen carcasses). Storage not only saves food for later use but also enables coyotes to share an abundance of food, because one coyote's store is frequently recovered by another. At times it appears that habitual storage locations are used. The food-storing behavior of coyotes appears to be an innate, fixed pattern, for pups as young as 6 weeks old have performed this series of actions with no opportunity to observe the pattern in others. The same pattern has also been observed in kennels with concrete floors, where actual digging and covering were precluded.

Evaluation of Fencing to Exclude Depredating Coyotes. — A 2.5-year contract with Oregon State University to evaluate electric and nonelectric fences to exclude coyotes from sheep pastures is nearing completion. Captive coyotes were trained to run a specific route within a large enclosure and various test fences were then placed across the coyotes' route of travel. In subsequent tests at Oregon State University and at the Service's Denver Center, captive coyotes were trained to kill live prey (rabbits), and then the coyotes and tethered rabbits were placed on opposite sides of test fences.

The Oregon State study evaluated 34 configurations of electric and nonelectric fencing and made recommendations as to mesh size, height, overhangs, and aprons. The researchers found that electric fences usually did not deter captive coyotes from killing tethered prey and that wires could not be positioned in such a way that coyotes always received a shock. However, after certain modifications, workers at the Denver Center found that a three-strand electric fence was effective in deterring captive coyotes from crossing to attack tethered rabbits. These studies have provided the data



A trainer encouraging Komondor guard dogs to be aggressive towards coyotes. Training of these dogs to protect domestic sheep from coyote predation involved teaching them to respond to obedience commands, avoid harassment of sheep, be aggressive towards coyotes, and remain within fenced pastures with sheep. *Photo by R. T. Sterner.*

needed to undertake a field evaluation of fencing in the management of farm and semifarm flocks.

Guard Dogs Protect Sheep from Coyotes. — A pilot study to determine whether Komondor guard dogs could reduce coyote predation upon domestic sheep has been completed. Four of the large (85- to 120-pound), white, long-haired dogs underwent a four-stage training regime. The dogs were obedience-trained, paired with sheep to observe dog and sheep interactions, taught to respond aggressively to coyotes, and trained to remain within a fenced pasture. One field-test site in Montana and two in North Dakota were then selected, and coyote kills of sheep were documented for 20 days before placing a pair of dogs on a test site. The dogs remained on each test site for 20 days while damage assessment continued. The dogs were then removed and assessment of coyote kills continued for 20 additional days, after which the data were tabulated and summarized.

Coyotes killed 50% to 75% fewer sheep when the dogs were present, indicating some potential for deterring coyote predation — at least for some farm and semifarm flocks. One pair of dogs began harassing sheep during the later stages of the

Montana test and continued to do so despite a determined effort by the technician to halt this behavior. It is hoped that a different approach to the selection and training of the Komondors will prevent undesirable behavior in future tests.

Coyote Mortality and Dispersal in South Texas.

— Sixty-three coyotes were instrumented with mortality-sensing transmitters during the first 2 weeks of November in 1974 and 1975 in Webb County, Texas, and 21 have been recovered as mortalities. Of these deaths, 71.2% were caused by man (gunshot, trap, vehicle), 14.3% were due to natural factors (malnutrition, mange, disease, or a combination of these), and 14.3% were from unknown causes (carcasses decomposed when located). The mortality rate of juveniles was significantly higher than that of adults.

Dispersal occurred during the last 2 weeks of November. Juvenile females were the mobile segment of the population. Eight of the nine dispersing coyotes were juvenile females, and they moved an average distance of 21.5 miles. Dispersing juvenile females had a human-induced mortality rate double that of nondispersing juvenile females (50% and 25%).

Control of Problem Coyotes by Toxic Collars on Sheep. — The toxic collar for sheep exploits the coyote's typical attack behavior by placing a toxicant-filled reservoir on sheep where it will be broken by attacking coyotes. The toxic collar is essentially a passive delivery system (in contrast to the M-44, which shoots sodium cyanide into the coyote's mouth), and the toxicant should not have aversive properties if a coyote is to self-administer a lethal dose. A polyvinylchloride collar filled with sodium cyanide, developed in 1975, killed 9 of 12 coyotes attacking sheep in pen tests. In field tests during August and September 1975 in North Dakota, Montana, and Texas, 14 tethered lambs wearing similar collars were attacked by coyotes, and collars on 8 of the lambs were broken. None of the attacking coyotes was known to have been killed, suggesting that the caustic taste and strong odor of the poison repelled them. Research thus far indicates that the toxic collar will control problem coyotes if a suitable toxicant can be found. This method of control may be costly, limiting its use to problem coyotes that elude other controls.

A search to find a more suitable toxicant has been under way since September 1975. The search involves literature review, consideration of specific chemicals within a given class, and consultation with representatives from industry and academic circles.

Tests of acute oral toxicity were conducted with 11 of the hundreds of chemicals for which information was given. Of these 11 chemicals, it was determined that only 4 (diphacinone, mandelonitrile, 4-aminopyridine, phosphamidon) merited testing in toxic collars with penned coyotes. Diphacinone, an odorless, tasteless oral anticoagulant used in rodenticide baits, was the only chemical that did not have offensive properties. In comparison studies of the effectiveness of the chemicals used in the collars, coyotes attacked sheep wearing either sodium cyanide or diphacinone collars. Puncture of collars containing sodium cyanide caused an abrupt cessation of the attack, whereas coyotes attacking sheep wearing diphacinone collars persisted in attack until the sheep were killed. Estimates of the volume of toxicant ingested by these coyotes showed that larger doses of diphacinone than of sodium cyanide were ingested. In field trials with diphacinone, many of the toxic packets had multiple punctures after an attack, indicating that diphacinone is not offensive to coyotes. In contrast, toxic collars containing sodium cyanide never had more than one packet punctured.

Despite the nonaversive properties of diphacinone, the chemical has an important shortcoming — several days are required for a coyote to succumb to a lethal dose. A lethally dosed animal can continue to attack lambs before it dies. Thus, it is difficult to evaluate the efficacy of diphacinone for toxic collars in the field because of the long interval between dosing and death of the coyote. New (immigrating) depredating coyotes could enter the population as rapidly as the resident coyotes could be removed with diphacinone.

Researchers unanimously agree that an odorless, tasteless chemical that produces mortality within 24 hours is needed. The feasibility of microencapsulating cyanide chemicals to mask aversive properties is being investigated. Microencapsulation has not been uniformly successful in all chemical applications, but the technique may have utility for the toxic collar. The search for the ideal predicide for the toxic collar will continue, and additional sources that could supply such a chemical will be investigated.

Expanding Collars for Wildlife Transmitters. —

A collar attachment for wildlife transmitters has been developed that expands or contracts to fit an animal properly. Young animals can therefore be instrumented with no danger of outgrowing the collar. In a test, 1-day-old domestic lambs were instrumented with expanding collars that incor-

porated simulated transmitters weighing 60 g. A year later these collars were removed from the mature lambs. No abrasions or distressful effects on the animals were noted. This method of attachment can be used on deer, antelope, moose, and elk. Three types of mortality-sensing electronic circuits have now been designed for these expanding collars.

Hazards to Wildlife Associated with Rodenticide Baiting. — Under an Environmental Protection Agency (EPA) contract, the hazards associated with strychnine baiting for pocket gophers in Minnesota and for ground squirrels in Wyoming were evaluated. On the Sherburne National Wildlife Refuge, Minnesota, 1,638 acres were treated with a burrow-builder, using 0.5% strychnine-treated bait. Treated fields were scattered throughout 10 sections. Control was good — data from activity plots of pocket gophers showed 87.5% reduction in activity. Populations of other small rodents (quite low initially) declined significantly on the treated area but increased significantly on the control area. To measure secondary effects of strychnine, 36 raptors and 36 mammalian predators were equipped with radio transmitters but no effect was detected. Red-tailed hawks, American kestrels, great horned owls, badgers, striped skunks, a red fox, and a coyote were intensively radio-tracked during treatment; all those that used treated fields survived. Tracks and diggings of mammalian predators were frequently observed on the burrow-builder tracks after treatment. Red-winged blackbirds were selected as representatives of seed-eating birds, and 100 territorial males on both the treated and control areas were marked for monitoring during the treatment. Even though some treated grain was available on the surface, and marked birds were observed feeding in treated fields, only one bird, a mourning dove, was found killed by the treatment.

In south-central Wyoming, approximately 9,000 acres were baited with 0.5% strychnine-treated bait for controlling Richardson's ground squirrels. Approximately 1 tablespoon of bait was placed from horseback at or near each ground squirrel burrow. Effectiveness of the treatment varied; some study plots showed almost no control of ground squirrels and others indicated over 90% control. Many territorial horned larks in baited areas were killed by the treatment. Before treatment, territorial horned larks averaged two per acre. After treatment, an average of 1.5 dead horned larks were found per acre searched. Some red-winged blackbirds, Brewer's blackbirds, yellow-



Richardson's ground squirrel. Ground squirrels, while an important food source to several avian and mammalian predators, can cause significant damage to agricultural crops. Photo by T. A. Gatz.

headed blackbirds, and cowbirds were killed by the treatment. Bait was being distributed as some birds were migrating through the area, and dead blackbirds, especially red-winged and Brewer's were found on most plots. Red-winged and yellow-headed blackbirds were not totally annihilated in baited areas but were reduced in number. Telemetry indicated that at least some of the survivors were not feeding in baited areas. Average numbers of dead birds found per acre searched were 0.5, 0.5, and 0.16 for red-winged, Brewer's, and yellow-headed blackbirds, respectively, and 0.05 for cowbirds. Mourning doves did not arrive until early May, when baiting was well under way, but doves that fed in baited areas proved likely to be killed. Dead doves on most plots searched (average, 0.35 dove per acre) and radiotelemetry data indicated that at least 25% of the radio-equipped doves died from eating the bait. Averages for other dead birds found per acre searched were 0.1 for vesper sparrows and 0.025 each for meadowlarks, starlings, savannah sparrows, and crows. The control program appeared to have no effect on raptors or mammalian carnivores.

These studies indicate that strychnine bait properly applied with the burrow-builder for the control of pocket gophers is a relatively safe procedure with few hazards to nonrodent wildlife. However, strychnine bait applied to the surface near holes of ground squirrels kills many seed-eating birds.

Antler Growth Suppressed by Diethylstilbestrol in White-tailed Deer. — Tube-type implants containing diethylstilbestrol (DES) were tested in male white-tailed deer as a method of controlling deer populations in National Parks. In mid-April

Florida Water Rat Well-established in Florida Sugarcane. — In cooperation with the Florida Sugar Cane League and the Virginia Cooperative Wildlife Research Unit, the distribution and depredations of the Florida water rat are being studied in southern Florida. It is one of several rat species that damage Florida sugarcane. It lives in distinct burrow systems irregularly scattered in infested sugarcane fields of about 35 acres each. In January-March 1976, a survey of its distribution and relative abundance was conducted on lands of the Western Division of the U.S. Sugar Corporation, which represents about 10.8% of Florida's sugarcane crop. Approximately 26% (237 fields) of all fields harvested in the Western Division area were selected at random and were examined for presence of burrows. Forty-one percent of the fields showed evidence of burrowing activity. The mean number of burrow systems per acre in infested fields was 0.28 (range, 0.02-1.39).

Vampire Bat Control and Paralytic Rabies. — Parasitism on cattle by vampire bats has long been a source of economic loss and hardship for cattlemen of Latin America. The transmission of paralytic rabies and possibly other diseases, blood loss, myiasis, and reduced production of milk contribute to a multimillion-dollar problem.

A research program aimed at developing methods for controlling vampire bats began in June 1968. It was funded by the Agency for International Development (AID), Department of State, under a Participating Agency Service Agreement with the U.S. Fish and Wildlife Service. Laboratory investigations were carried out in Denver, and other laboratory and field work took place at the Service's Vampire Bat Research Station in Mexico City, Mexico. This station officially closed in December 1973 after two safe, effective, and economical methods of control were developed, and research had shifted to observation of their use. The control techniques developed use the anticoagulant diphenadione and can be referred to as the "topical" and "systemic" methods. The topical method involves the capturing of vampire bats with mist nets set around corralled cattle or at cave entrances. Approximately 1.5 cc of a vaseline-diphenadione mixture is smeared on the dorsal surface of each captured vampire and the treated bats are then released. They return to their roost and, because they live in compact colonies, physically pass the toxicant from one to another. Lethal quantities are ingested while grooming. The systemic method involves the injection of a solution of diphenadione into the rumen compartment of

cattle. The diphenadione is absorbed into the bloodstream of the host and is later ingested in lethal quantities by the vampires that feed on blood from the cattle. There is no danger to adult cattle treated at the recommended levels. The techniques are about equal in effectiveness and can usually provide 90-95% reduction in parasitism as determined by examining the cattle for fresh bites.

Since 1974 AID has continued to fund the program, with the objective of having biologists from the Denver Wildlife Research Center help Latin American countries develop and initiate control campaigns. They could also study special problems associated with application of the techniques. Nicaragua has been the most aggressive country in putting these tools to use. In 1974 the Ministry of Agriculture initiated a national campaign for control of vampire bats. Statistics tabulated for the first 3 years of this program are impressive; a total of 240,461 cattle were examined and found to have 114,629 fresh vampire bites. The systemic method was used to treat 134,692 cattle, and 2,338 vampires were treated with the topical technique. The overall reduction in vampire parasitism for the 3-year period was 90.7%.

In June of 1976, the Nicaraguan Ministry of Agriculture sponsored the First International Symposium on the Control of Vampire Bats and Problems Associated with Paralytic Rabies. They stated that in 1975 there was not a single case of paralytic rabies reported from areas where control methods had been applied. They believe that paralytic rabies is being eliminated in Nicaragua.

Vampire Bats and Bovine Milk Production. — Parasitism by vampire bats has been alleged to have serious adverse effects on livestock health and milk production in Latin America, even where rabies is not present. To explore this question, milk production and blood indicators were measured in 58 Holstein cows from a dairy herd near Quito, Ecuador, and 28 mixed-breed cows from a dairy herd near Managua, Nicaragua, before and after parasitism by vampire bats (averaging two to four fresh bites per cow per night) was reduced 97-100% by systemic treatment. In Ecuador the climate was mild, the cows were well managed and healthy, and milk production was high before treatment; in Nicaragua the opposite was true. After treatment, blood packed-cell volumes increased significantly ($P < 0.05$) in both herds but milk production and hemoglobin counts increased significantly only in the Nicaraguan cows. These findings indicate that moderately severe parasitism by vampire bats has little or no influence on the milk production of



Vampire bats (*Desmodus rotundus*) transmit paralytic rabies to cattle throughout much of Latin America, resulting in thousands of cattle deaths each year. Lowered milk production, hide damage, and infected wounds, combined with rabies deaths, make this species a serious pest of livestock. U.S. Fish and Wildlife Service photo.



Vampires lap blood from small bites, most commonly made around the feet or legs of cattle. U.S. Fish and Wildlife Service photo.



A cooperative project between the Denver Wildlife Research Center and the U.S. Agency for International Development led to development of an injectable anticoagulant formulation which has proven to be an effective, low-cost method of controlling bat predation. U.S. Fish and Wildlife Service photo.

otherwise healthy cows in a mild climate but is detrimental to health and milk production in cows already under stress from poor diet, devitalizing climate, and diverse parasites. Thus, where rabies is not a factor, the economic benefits of vampire bat control may be only marginal for healthy, well-managed cows but of definite value for low-producing, poorly managed cows in tropical environments. This research was funded by the Department of State, Agency for International Development.

Young Calves Susceptible to Diphenadione. — The systemic method for controlling parasitism on Latin American cattle by vampire bats involves the injection of the anticoagulant diphenadione into the rumen compartment of the bovine stomach. Diphenadione is absorbed into the bloodstream of the host and is later ingested in lethal quantities by the bats as they feed on blood from the cattle. The procedure has been shown to be highly effective and safe when used on adult cattle. However, laboratory and field data indicated that some

hazard may be involved when it is used on very young calves. Young suckling calves were treated by this method and the effects monitored to determine if, in fact, they are more susceptible to diphenadione poisoning than adult cattle. In addition, a possible antidotal procedure was examined as well as the effect on toxicity to bats of blood from animals treated with the antidotal compound. This research was funded by the Department of State, Agency for International Development.

Evidence accumulated to date shows that (1) young calves, lacking a fully functional rumen and primarily dependent on milk for sustenance, are much more susceptible to diphenadione poisoning than adult cattle; (2) single intramuscular injections of Vitamin K3 given at the time of treatment with diphenadione did not offer complete protection against diphenadione poisoning in young calves; and (3) blood from calves treated with diphenadione and Vitamin K3 is as toxic to vampire bats as that from animals treated only with diphenadione. These results indicate a high degree of risk in using the systemic method of vampire control on young calves, and the use of the procedure on calves less than 4 months old is discouraged.

Crop Protection by Nonlethal Electric Barrier.

— Research in the Philippines funded by the Agency for International Development, Department of State, includes development and experimental application of nonlethal electric barriers to protect crops from rat depredations. For example, where dry-season planting of crops is practiced on irrigated land, rats from neighboring areas move into the plantings for food and shelter. Barriers would have the advantages of permanence and low labor costs in these situations. In addition, such barriers could be used for isolation of croplands from areas where rat densities are high, such as marshes and coconut groves, and for protection of small plantings of high-value crops.

A small-scale field test of a nonlethal electric barrier produced limited but highly encouraging results. The study area in the Philippines consisted of four 0.5-acre plots each planted with 10-week-old rice. Two plots were fenced with a nonlethal barrier charged electrically with a commercial livestock shocker; the other two plots were left unfenced in order to estimate normal damage to the crop. The fence was 14 inches high and constructed with bamboo stakes and 0.5-inch-mesh chicken wire. Two electrically charged wires and two ground wires, spaced 6 inches apart, were fastened with insulators to the bamboo stakes.



Ricefield rat attempting to climb a nonlethal electrical barrier in order to feed from a small container of rice. Detailed behavioral analyses of the rat-climbing activity is monitored through a closed-circuit television camera in the foreground. A 95% level of crop protection was observed with this barrier design in a field test in the Philippines. Photo by J. Stanfield, *National Geographic Magazine*.

Estimates of crop damage, conducted about 2 weeks before harvest, showed less than 1% of the stems cut by rats on the two fenced areas as opposed to over 13% on the unfenced areas. These data show a 95% level of crop protection with the prototype barrier design.

Laboratory work is progressing to substitute less costly materials for barrier construction. A field test of the prototype design, on a larger scale, is also now under way at the International Rice Research Institute in the Philippines.

Fox Squirrels Repelled by Methiocarb-treated Corn Seed. — Methiocarb repellency to fox squirrels was tested to determine the primary hazard of methiocarb-treated corn seed to this species. Ten captive fox squirrels were offered several choices of untreated and treated food. Squirrels consumed significantly less untreated dog food than untreated corn seed ($P < 0.01$), less treated corn than untreated corn ($P < 0.01$), and less treated corn than untreated dog food ($P < 0.01$). All squirrels survived an 18-day period during which only methiocarb-treated corn was offered; mean weight loss (127 g) during this period was significant ($P < 0.01$).

Methiocarb's repellency to the test squirrels and the survival of the squirrels after prolonged feeding on only methiocarb-treated corn indicate that the use of this treatment on corn seed poses little, if any, immediate hazard to fox squirrels. However, potential long-term effects, especially on reproduction, require further investigation to confirm safety. The results also suggest that methiocarb may have potential as a mammal repellent.

Methiocarb Protects California and Washington Sweet Cherry Orchards from Bird Damage. — From April through June 1976, methiocarb, a bird-repellent insecticide, was tested to determine its effectiveness in reducing bird damage to ripening sweet cherries in California and Washington. In each state, 12 orchards ranging in size from 1.5 to 6.0 acres, with early maturing varieties and high probabilities of bird damage, were selected for testing. Six of the 12 orchards were sprayed with 2.0 pounds (active ingredient) methiocarb in 200-250 gallons of water per acre from 10 to 14 days before the anticipated start of harvest, and 6 were left untreated.

Before the onset of bird damage (12-20 days before harvest), 40 trees were randomly selected in each orchard, and 50 outermost cherries on one randomly chosen branch were marked in each tree. Just before harvest, the numbers of bird-damaged, missing, and undamaged cherries were counted on these samples.

Methiocarb provided protection from bird damage in each state. In California, untreated orchards received about 3.2 times the damage of treated orchards (3.77% vs. 1.18%), and in Washington untreated orchards had 7.5 times as much damage (3.28% vs. 0.43%).

Bird counts supported the damage findings. Untreated orchards had about twice as many birds as treated orchards in California and about three times as many in Washington. In descending order



A mist blower applies methiocarb to sweet cherries in a bird-repellent trial in California. Photo by O. E. Bray.

of abundance, robins, waxwings, and house finches were most common in California and house finches, robins, and starlings in Washington.

These results should enable the manufacturer to obtain a bird repellency label for methiocarb to combine with the insecticide registration for sweet cherries. This label would be the first granted to a chemical for protection of fruit from bird damage.

Methiocarb Remembered by Redwings. — Redwinged blackbirds can remember the repellent qualities of methiocarb for periods up to 16 weeks after initial exposure. Laboratory tests at the Pennsylvania Field Station have indicated that after learning an aversion to methiocarb, the repellent response, measured by the amount of time spent feeding in a 5-minute exposure, is undiminished up to 4 weeks after learning and is still strong at 16 weeks. Other data on the characteristics of redwing responses to methiocarb indicate that this species forms an aversion to the taste of methiocarb rather than to the food base. This finding is in contrast to some published data indicating that laboratory and wild Norway rats often form aversions to the food in which the aversive agent is presented rather than to the agent. The redwing data are needed so that the potential use of methiocarb as a protectant for agricultural crops may be properly assessed.

Avitrol Registered for Sweet Corn and Sunflowers. — On the basis of data from studies conducted in 1974, federal registration for the use of 4-aminopyridine formulation, Avitrol FC Corn Chops-99S, in field corn was amended in August 1975 to include sweet corn grown in some regions. Registration does not include the States of New York, Pennsylvania, West Virginia, Kentucky, Tennessee, Arkansas, and Louisiana because adequate data on effectiveness of Avitrol were not

available for these northeastern and southeastern areas of the United States. In August 1976, a similar formulation, Avitrol FC Corn Chops-99S, was federally registered for protection of ripening sunflowers from starlings and certain blackbirds in North Dakota, South Dakota, Nebraska, Kansas, Oklahoma, Texas, Minnesota, Iowa, Missouri, Wisconsin, Ohio, Illinois, Michigan, and Indiana. These products of Avitrol Corporation are for use by or under the supervision of government agencies trained in bird control; they are not for sale to the public.

Methiocarb Fails to Protect Michigan Sour Cherry Orchards from Bird Damage. — In 1976 randomly selected halves of eight tart cherry orchards in Michigan were either treated with 2.0% (active ingredient) methiocarb at approximately 14 and 7 days before harvest or were left untreated as controls. Estimated damage in treated and untreated halves did not differ significantly. In the orchard with the most bird damage, as measured by missing cherries and bird-pecked cherries, damage was 40% greater in the treated half than in the control half (20.5% vs. 14.5%). For all eight orchards, damage in the treated units and the untreated units each averaged 5.6%.

Intensive observations of birds indicated more bird activity in the treated than the untreated plots. Twelve species were observed feeding on cherries, with robins and starlings the most common.

Because of several factors, including slight precipitation after spraying, the presence of birds in the orchards, and the fact that damage did occur, we believe that this investigation was an adequate test of methiocarb. We conclude that methiocarb cannot be considered an effective bird repellent for sour cherries.

Registered Avitrol Treatment for Sweet Corn May Need Formulation Refinement. — Experimental Avitrol treatments applied to fields of sweet corn in Ohio, Maryland, and New York in 1974 did not reduce damage by blackbirds. The bait, cracked corn with 1% of the corn particles treated with 4-aminopyridine, was applied aerially at the rate of 1 lb/acre, usually every 4 days, to selected fields that were within 12 days of their projected harvest. All application restrictions specified in the registration label for use on field corn were followed. The lack of success of the Avitrol treatment in the three tests was presumably due, at least in part, to the lower blackbird population densities and the low number of reacting birds at the experimental sites.

A review of the factors involved in Avitrol cracked-corn treatments suggests that the best way

to make the treatments effective is to increase the proportion of treated corn particles (i.e., a change in product formulation). A change in the rate of application (1 lb/acre) seems less desirable because chances for ingestion of a treated particle during any episode of small-flock feeding would not be increased substantially by an increase in application rate. Higher rates of treatment of either type, however, might substantially increase the kill of nonblackbird species. Further evaluations are needed to solve this problem.

Census of Blackbirds and Starlings in Winter Roosts in the United States, 1974-1975. — The sixth national survey of blackbird-starling roosts was conducted by the Fish and Wildlife Service during the winter of 1974-75. Most of the data collection was through Regional Offices. Cooperating ornithology students, whose participation was solicited through the National Audubon Society, increased survey coverage. The data collected were analyzed at the Patuxent and Denver Wildlife Research Centers. Data from the East and West were combined in an 81-page report in 1976.

In all, 723 roosts with an estimated 537 million blackbirds and starlings were reported in the United States. In the East, 358 roosts with 398 million birds (74% of the national population) were found; in the West, 365 roosts and 139 million birds (26%) were reported. The national population was composed of 11 species: red-winged blackbirds (38%); common grackles (22%); starlings (20%); brown-headed cowbirds (18%); Brewer's blackbirds (2%); the remainder (trace) included rusty blackbirds, boat-tailed grackles, great-tailed grackles, tricolored blackbirds, yellow-headed blackbirds, and bronzed cowbirds.

Most roosts in the East were in hardwood thickets (41%) or coniferous stands (34%); others were in cane, marshes, man-made structures, or street trees. In the West, about half of all roosts were in marsh habitats and most others were in various types of woody vegetation. Field work in intervening years between the 1969-70 and 1974-75 surveys indicated that 25-50 roosts, each of a million or more birds, were unreported.

Most Banded Blackbirds and Starlings Recovered at Spring Roosts in Ohio Were Banded Near Roosts. — After wetting agent treatments at three early-spring roosts in central Ohio, 219 banded redwings, grackles, cowbirds, and starlings were recovered. Of these, 154 (70%) had been banded at various times during the year within 100 miles of one or another of the roost sites. The recovery of such a large proportion of birds within 100 miles of



A nesting male red-winged blackbird about to enter a decoy trap and acquire a band and leg streamer. Photo by O. E. Bray.

their roosts indicates that many of the roost occupants are probably in northern Ohio during the period when crop depredations occur and may be those most responsible for the damage there. Other birds were migrating through central Ohio en route to breeding grounds in more northerly latitudes, as indicated by the recovery of 59 (27%), all spring-summer-, and fall-banded birds that had been banded at locations 100-300 miles away in western New York, southwestern Ontario, southeastern Michigan, and the northern corners of Ohio. Six (3%) winter-banded birds had been banded 400-600 miles to the southwest (in Alabama or Tennessee). Some evidence was found for use of traditional sites along the north-south migratory pathway and for flock tenacity.

Songbirds Commonly Damage Sunflowers in Ohio. — In 1974, about 40% of the birds feeding in nine commercial sunflower fields in Sandusky County, Ohio, were songbirds (e.g., goldfinches, sparrows, and cardinals) and doves. The remaining birds were either blackbirds or house sparrows. Estimated bird damage in these fields averaged 3.6% (range 0.7-10.0). These observations suggest that certain songbirds commonly use and feed in commercial sunflower fields in northern Ohio, and therefore any proposed technique for reducing blackbird damage to these fields in Ohio should be carefully tested for hazards to nonblackbird species.

Bird Hazard to Aviation Increasing. — Many bird/plane strikes, 1973 through 1975, resulted in engine ingestion of birds, causing serious damage

and loss of aircraft and human life. Executive jet engines appear very vulnerable to bird damage. Five of these aircraft have been lost due to engine ingestion of birds — Lear Jets at Atlanta, Georgia (cowbirds) and Watertown, South Dakota (gulls); and an HS-125 at Downsfold, England (lapwings). All passengers were killed in the Atlanta accident, occupants were injured at Watertown, and six people in a car were killed when struck by the HS-125. Many serious bird/plane strikes involving commercial aircraft have occurred throughout the world; the wide-bodied jets, particularly the 747 and the DC-10, appear as vulnerable as older aircraft. Most of the serious strikes occurred during takeoff, a most hazardous situation because many of these aircraft were heavily loaded international departures. Many serious strikes have involved gulls, species that are an increasing worldwide hazard. Known techniques for keeping runways and airport areas free of gulls (and other birds) are apparently not being routinely and responsibly applied, and the record indicates that extreme bird hazards are present. The recent loss of a DC-10 on takeoff at JFK Airport is an example of these hazards.

The present critical need of both civil and military aviation in the United States is a systematic program to bring about responsible and continued use of known remedial measures. The record of incidents and losses indicates that highest priority should be given to effecting measures for repelling birds — particularly gulls, blackbirds, and starlings — from airports, especially from runways and adjacent areas. In addition, military low-level missions should not be flown in areas of high bird hazard.

Starlings Only Threat to Winter Wheat in Tennessee. — Starlings inflicted 100% of the damage to sprouting winter wheat in the winter of 1975-76 in Gibson County, Tennessee, where an 11-million-bird blackbird/starling roost was located. Wheat made up 41% of the food items in starlings collected in November, in contrast to 0% for grackles, red-winged blackbirds, and brown-headed cowbirds. A survey of 48 randomly selected wheat fields in the foraging area of the roosting birds revealed that 31% of the fields had been damaged by starlings (i.e., pulling out emerging sprouts). Overall, an estimated 3.5% of the wheat sprouts were removed from the 48 fields. The best way to reduce or eliminate damage is to plant fields by early November. The 33 fields planted before November 13 sustained no bird damage, but all 15 fields planted on that date or later received some damage.

Differences Between Bird and Mammal Toxication Systems. — Microsomal mixed-function oxidative enzymes in the livers of animals play important roles in the toxication and detoxication of foreign compounds. These hepatic enzymes or enzyme systems are being studied as a means of developing chemicals that will selectively alter the physiology or behavior of depredating animals. In recent studies, *p*-chloroaniline was found to be a good model in the comparative study of the *N*-hydroxylation (a toxication process) of primary aromatic amines by male red-winged blackbirds and albino rats. Various reaction parameters were

investigated. Under optimum reaction conditions, the *N*-hydroxylation activities of redwing hepatic microsomes were about 2.5 times lower than those of analogous preparations from rat livers. The microsomal protein and cytochrome P-450 concentrations of the hepatic microsomes of both species were also found to differ. Both concentrations had significantly smaller values in birds than in rats. Exploitation of these and other basic avian-mammalian differences could lead to control methods that would affect only the target animal — and not other animals or the environment.

Environmental Contaminant Evaluation

FISH-PESTICIDE RESEARCH LABORATORY

Acute Toxicity of Chemicals. — Capabilities of the Fish-Pesticide Research Laboratory and its field stations for research on acute toxicity were integrated to meet the needs for two major data bases. The most urgent need for such data related to the Fish and Wildlife Service's concern that massive spraying operations for spruce budworm control in the northeastern United States may adversely affect the restoration of Atlantic salmon, as well as damage other aquatic resources. Technical and field formulations of several registered and experimental insecticides were investigated in these studies. The U.S. Forest Service provided sufficient field data and information on anticipated use patterns to enable us to design research applicable to appropriate species and water types representative of the areas to be treated. Results of the work were used by the Regional Office, Boston, Massachusetts, in modifications of overall spraying operations to reduce the effects of the insecticides on aquatic resources.

The second major effort of this section involved testing several technical and field formulations of herbicides. Special emphasis was placed on glyphosate, which appears environmentally safe and effective for vegetation management. Results of the research on herbicides and forest insecticides

are summarized in later sections of this report.

Other chemicals tested for acute toxicity included manufacturing contaminants of pentachlorophenol and three water-soluble fractions of crude oil. Accidental spills of pentachlorophenol, which is commonly used as a wood preservative, have caused fish mortalities in Missouri and elsewhere. However, this compound also contains dioxins and dioxin precursors (predioxins) which exist at concentrations up to 0.1%. Dr. C. Rappe, University of Umea, Sweden, who has synthesized three predioxins, has provided us with small amounts of these chemicals for preliminary toxicity tests. The 96-hour LC50's for all three predioxins to scuds, midge larvae, and fathead minnows were greater than 0.5 mg/l. Longer tests will be required to determine whether these impurities contribute significantly to the toxicity of pentachlorophenol. Studies of the toxicities of three water-soluble fractions of crude oil — toluene, benzene, and ethyl benzene — to bluegills yielded 96-hour LC50's of 1 to 50 mg/l.

Overall, 30 chemicals were tested for their acute toxicity to fish and aquatic invertebrates. The data generated were more definitive than those from past acute toxicity studies in that a greater number of species were tested in a variety of waters simulating different biogeographical areas. The results of these tests also indicated that 16 of the 30 chemicals should be considered for more detailed

research. Personnel in the section responded to more than 100 requests from chemical industries, Federal and State agencies, and other researchers for acute toxicity data.

Orthene Appears Safest of Proposed Forest Insecticides. — The Fish-Pesticide Research Laboratory continued research support of both the Fish and Wildlife Service's Atlantic salmon restoration program and the Forest Service's forest insect control programs by estimating the relative environmental acceptability of candidate insecticides. In 1975 and 1976, the Forest Service sprayed more than 5.5 million acres in Maine and Montana to control the spruce budworm. The areas sprayed involve divergent biogeographical regions with various water qualities and associated aquatic organisms. In 1976, Dylox, Matacil, Orthene, Sevin, Sumithion, and Lannate were tested against species characteristic of cold-, cool-, and warm-water habitats, and in water types characteristic of the areas to be sprayed.

All of the insecticides tested were many times more toxic to aquatic invertebrates than to fish. The 96-hour LC_{50} 's of technical grade Dylox, Matacil, Sevin, and Sumithion ranged from 3 to 40 $\mu\text{g/l}$ for scuds, stonefly naiads, and midge larvae, and from 1,600 to 3,900 $\mu\text{g/l}$ for cutthroat trout, brook trout, bluegills, and yellow perch. In contrast, the toxicity of Orthene was about 10,000 $\mu\text{g/l}$ to invertebrates and over 100,000 $\mu\text{g/l}$ to fish. The field formulation of Matacil was about 70 times more toxic to fish than its technical form, and the difference was apparently due to some additive in the formulation. Toxicities of the six insecticides tested were altered in waters of different temperature, hardness, or pH. For example, the toxicities of Dylox, Matacil, and Sevin to fish were 4 to 21 times greater in water of pH 8.5 than in water of pH 7.5. Therefore these chemicals could pose a greater hazard to aquatic organisms in Montana (where stream pH is commonly 8.5 to 8.8) than in Maine (where pH is lower). In rainbow trout and channel catfish, eggs were relatively more resistant to all of the insecticides than were swim-up fry and fingerlings.

Field studies by the Forest Service show that water collected 30 and 120 minutes after an aerial application of Dylox in 1975 contained residues of 260 and 7 $\mu\text{g/l}$, respectively. If such residues in water are representative of what might also be expected for Orthene, Sevin, Sumithion, and Lannate, these insecticides should not cause significant fish mortalities. However, comparable residues of the field formulation of Matacil could kill fish. All of the insecticides tested, except

Orthene, may cause significant mortalities of stream invertebrates and affect fish populations indirectly by reducing their food. Overall, our acute toxicity studies suggest that the field formulation of Matacil is the least, and Orthene the most, environmentally acceptable of the six chemicals tested for spraying near aquatic habitats.

Experimental Insect Growth Regulator Tested Against Aquatic Organisms. — Dimilin (TH 60-40) is an insect growth regulator that inhibits maturation of juvenile insects. It is among a group of new compounds that have been proposed as being environmentally safer than the more conventional insecticides. Insect growth regulators, which are not supposed to be directly toxic to target insects, produce structural changes during insect development that indirectly cause mortality. Dimilin shows high biological activity against a variety of target pest insects, and experimental permits for its use on gypsy moth, spruce budworm, cotton boll weevil, and mosquitoes have been granted by the Environmental Protection Agency.

Because Dimilin may be used extensively in or near aquatic habitats, we determined its toxicity to invertebrates and fishes inhabiting cold and warm waters. Because of the unique mode of action of this compound in inhibiting metamorphosis of immature insects, we were not surprised to find it relatively nontoxic to fish. The acute, static 96-hour LC_{50} 's were greater than 100 mg/l for rainbow trout, fathead minnows, channel catfish, and bluegills. However, crustaceans such as daphnids and scuds were highly sensitive to Dimilin; 48-hour EC_{50} 's ranged from 15 to 45 $\mu\text{g/l}$. In contrast, midge larvae were less sensitive than crustaceans (48-hour EC_{50} 's, 560 $\mu\text{g/l}$), but chronic exposures showed that emergence of adult midges was reduced 25% by a concentration of only 6 $\mu\text{g/l}$.

Three degradation products of Dimilin were also tested for their acute toxicity. The most toxic of the three was 4-chloroaniline; the 48-hour EC_{50} was 43 mg/l for midge larvae and the 96-hour LC_{50} was 2.4 mg/l for bluegills. Comparable values for 4-chlorophenyl urea and 2,6-difluorobenzoic acid exceeded 100 mg/l for midge larvae, rainbow trout, channel catfish, and bluegills.

Based on the maximum recommended application rate of 0.16 pound of Dimilin to 1 acre-foot of water (0.06 mg/l) for mosquito control, no acute adverse effects on fish would be expected, but populations of important fish food organisms, such as crustacea and midges, could be reduced.

Research on Herbicides. — Herbicides are used extensively by Federal agencies to manage

vegetation on public lands and in or along irrigation and reservoir systems. Such chemicals may enter aquatic habitats by intentional direct application to water or by unintentional drift and runoff from adjacent land. For example, in 1975 the U.S. Bureau of Reclamation used over 1.5 million pounds of herbicides to control vegetation associated with western irrigation systems, and the Fish and Wildlife Service applied 340,000 pounds on refuge lands and fish production facilities. Several ester formulations of 2,4-D are used by the Forest Service to stimulate grass production through sagebrush control. Earlier, we found that the butyl ester (BE) and the propylene glycol butyl ether ester (PGBEE) of 2,4-D were toxic to lake trout at concentrations of about 1,000 $\mu\text{g/l}$, and that longer exposures to concentrations down to 33 $\mu\text{g/l}$ adversely affected young trout. In 1976, we conducted similar tests with cutthroat trout because they are more closely associated with streams in the sprayed areas than lake trout, and some strains of cutthroat trout are on the endangered species list. Toxic concentrations for cutthroat trout were in the range of 320 to 350 $\mu\text{g/l}$, but exposure to a single application of 100 $\mu\text{g/l}$ had no effect on fry or fingerlings. However, continuous exposures of the young to concentrations of 20 to 30 $\mu\text{g/l}$ reduced growth and survival. Field investigations by the Forest Service show that residues of 2,4-D BE or 2,4-D PGBEE may reach 1,000 $\mu\text{g/l}$ in streams after spraying and persist at lower concentrations for about 10 days. Because such concentrations pose a significant hazard to fisheries, our results were submitted directly to the Forest Service for consideration in future sagebrush control procedures.

Simazine and 2,4-D DMA are now registered by the Environmental Protection Agency (EPA) for certain aquatic weed problems associated with navigation, irrigation, and management of fishery habitats. These registrations were contingent on our residue and toxicological investigations over the past 3 years. Chronic toxicity studies in 1976 were designed to detect sublethal effects of the two chemicals under contrasting conditions of continuous exposure and exposures simulating actual use. Under the latter condition, Simazine had no adverse effect on survival, growth, or reproductive success of fathead minnows, but continuous exposure to 2,500 $\mu\text{g/l}$ caused a 12% decrease in growth in fry. The 2,4-D DMA appeared to have no serious adverse effects on fathead minnows, but growth of young fish was stimulated by both continuous and use-pattern exposures.

In 1975, we found that some chemicals used to control plant growth in irrigation systems might influence distribution of fish in streams that receive irrigation return flows. Rainbow trout fry avoided sublethal concentrations of copper sulfate or xylene down to 0.1 $\mu\text{g/l}$ and 100 $\mu\text{g/l}$, respectively. They did not avoid acrolein before receiving a lethal exposure. We conducted similar studies in 1976 with mayfly nymphs and tested copper sulfate, xylene, acrolein, diquat, dalapon, Aquathol K, 2,4-D DMA, and Roundup. The nymphs did not avoid any of these chemicals at concentrations that might occur in irrigation return flows following weed-control applications at recommended rates. One of the herbicides tested in the avoidance studies, Roundup, was also investigated for its toxicity to fish and aquatic invertebrates because it is relatively new and appears particularly effective for control of emergent vegetation along irrigation ditch banks, or on refuges and fish hatcheries. It is being developed for various broad agronomic uses because it is relatively nontoxic to animals, immobile in soils, and appears highly degradable. The results showed that the active ingredient, glyphosate, was much less toxic to fish and invertebrates than the Roundup formulation. The 96-hour LC₅₀ for Roundup to fathead minnows was 2.3 mg/l, whereas the LC₅₀ for glyphosate to rainbow trout was 140 mg/l. The toxicity of the surfactant used in the formulated product was similar to that for the whole formulation. Also, the toxicity of Roundup in water was not reduced after aging for 7 days, probably due to stability of the surfactant. Sac fry and early swim-up fry of rainbow trout were more sensitive to glyphosate and Roundup than were the eggs. These results suggest that a change in the formulation of glyphosate would greatly improve its environmental safety.

2,4-D DMA Influences Pond Community Interrelations. — Research was begun in the summer of 1975 to identify major limnological characteristics of ponds that are most useful in monitoring and predicting impacts of contaminants on aquatic communities. Of 12 ponds used in the study, 4 were treated with 1 mg/l and 4 with 2 mg/l of 2,4-D DMA, and 4 were untreated. Twenty measurements of physical, chemical, and biological characteristics of the ponds were incorporated into a descriptive statistical model of related variables. Both concentrations of 2,4-D DMA suppressed the growth of occasional arrowhead plants (*Sagittaria montevidensis*) for about 6 weeks, but common water nymph (*Najas guadalupensis*) and stonewort

(*Chara* spp.), which together nearly covered the bottoms of the experimental ponds, were not reduced by even the high concentration. However, aerial photographs revealed that 1 mg/l apparently stimulated growth of submerged vegetation.

Several effects associated with the herbicide treatments appeared in nontarget organisms. Bluegills in ponds treated with 2 mg/l of 2,4-D DMA grew faster than fish from untreated ponds, or ponds treated with 1 mg/l of 2,4-D DMA. Laboratory tests in which phytoplankton was collected at intervals from untreated ponds and exposed to 2,4-D showed that 2 mg/l of the herbicide significantly increased algal production, but 1 mg/l did not. Although 2 mg/l increased algal production experimentally and increased photosynthesis in ponds, it is questionable whether increased production was responsible for the entire increased growth rate of fish in ponds treated with 2 mg/l of 2,4-D DMA. Other laboratory studies showed that 2,4-D DMA by itself can also increase growth and sexual maturation of fathead minnows.

Although 2,4-D DMA did not seriously affect the major rooted plant species, treatments of 2 mg/l influenced pH, turbidity, alkalinity, and conductivity and lowered the magnitude of diurnal oxygen changes in ponds. Such oxygen changes are good estimators of total biological productivity and suggest reduced photosynthesis due to a stress on the plant communities. This condition would probably increase cycling of plant nutrients, such as phosphates or nitrates, back into the pond water. Therefore, 2,4-D may stimulate algal production directly, as in the bioassay experiments, or indirectly by releasing more inorganic nutrients.

Variations in 14 water-quality characteristics (such as pH, turbidity, conductivity, and PO_4) of 2,4-D treated and untreated ponds were compared by stepwise multiple regression with concentrations of chlorophyll *a*, a measure of the weight of algae in water. In this analysis, only the factors which are most statistically significant are compared in the final computations. Turbidity was significantly associated with chlorophyll in the control ponds, whereas conductivity replaced turbidity as the single most statistically significant variable in ponds treated with 1 mg/l of 2,4-D DMA. In the high-treatment ponds, chlorophyll concentration was correlated with the inorganic phosphate, followed by turbidity and conductivity. Therefore, increased algal production in ponds treated with 2,4-D DMA is probably due to a combination of direct stimulation of photosynthetic activity, and (indirectly) increased release of macrophyte

nutrients. These investigations were continued during the summer of 1976 with relatively heavy treatments of two herbicides, dichlobenil and fenac.

Benthic Hydrosol Communities, Geochemical Cycling, and Contaminant Impacts. — The Nation's waters are one vehicle for the transport and distribution of synthetic chemicals and other industrial and agricultural wastes. However, monitoring of various pollution problems suggests that many such contaminants form complex associations with organic and inorganic particulate materials in water, some of which settle to the bottom and are incorporated into sediments. The bottom, or benthic, regions of aquatic ecosystems provide habitat for numerous invertebrates and other important fish and wildlife foods. These regions also support a relatively fragile, thin zone of microorganisms, usually no more than a few inches thick below the water-mud interface, frequently termed the hydrosol. This zone performs a vital function in the decomposition of biological matter, and in the recycling of inorganic nutrients back into production of fish and other essential components of aquatic communities. The well-being of all aquatic organisms is intimately interwoven with microbial activity in the sediments. It is well known that benthic microorganisms can modify or degrade various synthetic chemicals, but little is known about the types of microorganisms present, their microenvironmental requirements, or whether contaminants in sediments constitute a hazard to normal benthic microbial action.

Over the past year, Laboratory scientists modified and adapted about 15 agricultural and limnological techniques into a rapid screening test that infers impact or nonimpact of chemicals on the physiology of microorganisms in natural benthic hydrosols. The test is based on general physiological processes that are essential to recycling of carbon, nitrogen, sulfur, and phosphorus. Tests of 50 insecticides, herbicides, and industrial chemicals, including such materials as DDT, atrazine, Arochlor 1254, 2,4-D DMA, leptophos, hexachlorobenzene, and toxaphene, for activity against benthic microorganisms revealed that more than half of these affect the growth of microorganisms. More elaborate experiments are under way to determine which general physiological processes of the hydrosol communities responsible for cycling nutrients are affected by the contaminants. Also, we wish to determine whether effects on such processes are commensurate with real or expected concentrations of the contaminants in sediments, the hydrosol conditions associated with microbial

inhibition, and the relative sensitivity of benthic communities from other geographical regions. We believe such tests could become a powerful tool in estimating potential effects of new synthetic chemicals on cycling of nutrients in aquatic ecosystems, in interpreting data from environmental monitoring of chemical residues, and in general biological monitoring of aquatic ecosystems.

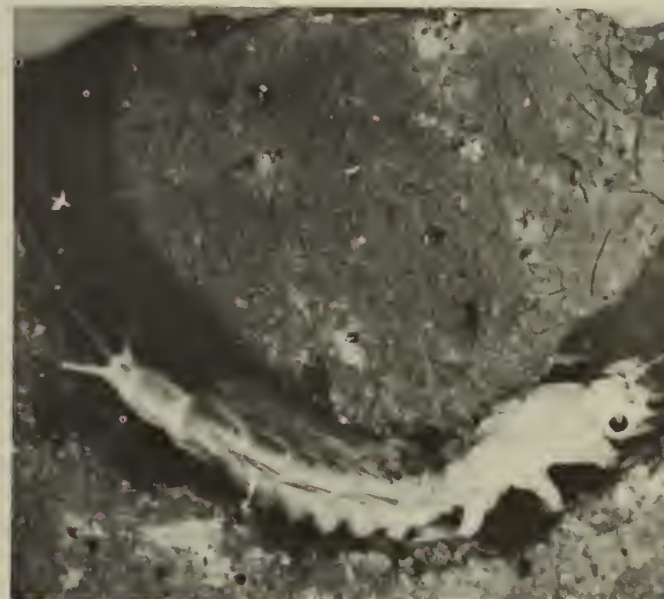
Modular Food Chain Research Nears Completion. — This 2-year investigation funded by the Office of Toxic Substances of EPA was undertaken to develop a reliable biological model for estimating the uptake, transfer, and degradation of xenobiotic chemicals in segments of an aquatic food chain. Partial results were reported in the 1974-75 Annual Report. A protocol for the modular food chain was published in the Federal Register in 1975. The major objectives of the research were to test the overall reliability of the model and to measure effects of different operating conditions on variability of data generated by the test system. These objectives have been met, and the data will be used in assessing the suitability of the model for pretesting of chemicals according to requirements of the Toxic Substances Control Act of 1976.

Mayflies Prove Effective in Monitoring PCB's. — The Upper Mississippi River provides important habitat for sport and commercial fisheries, but residue monitoring of fish from some segments of the river has revealed extensive pollution by polychlorinated biphenyls (PCB's). The burrowing mayfly, *Hexagenia bilineata*, is an important natural fish food in the Upper Mississippi River and is one of the most abundant aquatic insects in the navigation pools. We analyzed adult mayflies to better define benthic distribution of PCB's in the River because their immature forms (naiads) are relatively sedentary bottom dwellers, and the adults are abundant and easy to collect. Also, since the life cycle of mayflies is normally completed in 1 year, residue concentrations represent an annual accumulation which can be followed from year to year.

Adult mayflies, collected for us by public cooperators at 14 stations along 160 miles of the Mississippi River, contained PCB residues as high as 2.9 $\mu\text{g/g}$, based on whole body weight. Residue levels were highest in adult mayflies collected from the Lake Pepin area, a natural lake on the Mississippi River, which is about 60 miles downstream from Twin Cities, Minnesota. Generally, PCB residues in carp collected from this area were four to five times higher than those in



Mayfly adult (above) and naiad (below) in hydrosol from the upper Mississippi River. Photos by C. Fremling.



mayflies, probably because of the higher lipid content of the carp. The uptake of PCB's by mayfly naiads is probably by way of both water and food, since they live in burrows, and significant PCB residues in streams and rivers are believed to be associated with suspended materials and hydrosols. Much of the suspended material in the River settles to the bottom as it flows into Lake Pepin and current velocity slows. Thus, the lake may become a large settling basin for PCB's sorbed to sediments,

and benthic food-chain elements of the lake may accumulate considerable amounts of PCB residues.

An extensive survey of PCB residues in mayflies collected from the entire length of the Mississippi River, as well as from some of the major tributaries, is under way. Samples are also being collected from several pristine lakes in Minnesota and Wisconsin.

Aroclor 1254 (PCB) Impairs Growth and Development of Brook Trout. — Polychlorinated biphenyls are now considered a ubiquitous pollutant of freshwater ecosystems in the United States; residues in fish range from 0.1 to over 150 $\mu\text{g/g}$. Residues of this contaminant in important salmonid fishes of the Great Lakes, northeastern United States, and elsewhere prompted us to study its effect on growth of early life stages of brook trout, a widely distributed salmonid. We also wished to determine whether subtle, more sensitive biochemical measurements could detect adverse effects of PCB's.

Eyed eggs of brook trout were exposed to water concentrations of Aroclor 1254 ranging from 0.44 to 12.6 $\mu\text{g/l}$. After hatching, the fry were exposed for 120 days. Median hatch time, percentage hatch, and percentage sac-fry mortality were not affected. However, fry mortality increased in the highest exposure 7 days after yolk absorption. Mortality also increased in fry exposed to the lower concentrations, 10 to 80 days after yolk absorption.

The growth of brook trout fry was significantly reduced below that of controls by Aroclor 1254 concentrations of 1.5 $\mu\text{g/g}$ or higher at 10 days after yolk absorption. However, at 120 days after hatch, growth of the surviving brook trout was similar to or greater than that of controls. Biochemical observations of backbones in fish exposed for 80 days showed that collagen levels decreased and calcium increased at Aroclor 1254 concentrations of 0.71 $\mu\text{g/g}$ and greater. This collagen-calcium imbalance appears to be indirectly indicative of other toxicological disorders, which are discussed in the next section of this report, concerning the effects of toxaphene. The early developmental stages of brook trout were the most sensitive, and the initial effects on bone development remained evident through the later stages of growth. Fish with reduced growth at 10 days post-yolk absorption contained residues of 9 to 400 $\mu\text{g/g}$. The bioaccumulation (40,000 to 49,000 times) of Aroclor 1254 by brook trout was similar at all concentrations at the end of the study. However, during the sac-fry stage, fish in the lowest concentration had bioaccumulation factors three times greater than those of fish in the highest

concentration.

Further work on PCB's will involve the determination of the most persistent and toxic components. Recent studies with mice have shown that the toxicity of PCB's and their storage in fatty tissue vary widely with the positions of the chlorine atoms on the biphenyl ring. We have separated PCB's into subfractions, using activated carbon on polyurethane foam. These fractions contain PCB's with decreasing chlorine substitution in biphenyl *o,o'*-positions. Tests of the toxicity to fish and fish-food organisms of these fractions will provide a measure of their respective importance in PCB pollution and may permit more meaningful analyses of PCB residues.

Biological Impact of Toxaphene on Aquatic Organisms. — Toxaphene is an organochlorine insecticide used extensively in the southeastern United States for pests on cotton, and residues of toxaphene have been reported as high as 48 $\mu\text{g/g}$ in fish from that area. For the past several years, EPA has partially funded our research on toxaphene to assist in developing water quality criteria for this insecticide. However, the work was also directed toward toxicological interpretation of toxaphene residues in fish and their significance to fishery resources, and toward the development of biochemical techniques that may have utility as sensitive indicators of pollution-induced stress in the field.

Fish were more sensitive to toxaphene than were aquatic invertebrates. The acute toxicity of toxaphene to daphids (*Daphnia magna*), a scud (*Gammarus pseudolimnaeus*), and midge larvae (*Chironomus plumosus*) ranged from 10 to 180 $\mu\text{g/l}$, whereas the acute toxicities for brook trout, fathead minnows, and channel catfish were 4.1, 5.3, and 15.2 $\mu\text{g/l}$, respectively. Among invertebrates, daphnids were more susceptible to chronic exposures of toxaphene than scuds or midge larvae. Under chronic conditions, toxaphene had little effect on reproduction of brook trout, fathead minnows, and channel catfish; however, growth of offspring in each species was significantly decreased. In addition to length and weight being decreased by toxaphene, backbone development in each species was also impaired. Collagen synthesis in the backbone was inhibited and resulted in an increase in the ratio of minerals to organic matrix. As a result, vertebral columns of the fish became more brittle and susceptible to being fractured or broken. Toxaphene residues in fish from these studies were in the range of those reported in fish collected in national pesticide residue monitoring



Effects of 150-day toxaphene exposure and dietary vitamin C concentration on growth and skeletal development in channel catfish. A is a fish fed a diet containing 670 mg/kg of vitamin C and not exposed to toxaphene, B is a fish fed a diet containing 670 mg/kg of vitamin C and exposed to 475 mg/l of toxaphene, and C is a fish fed a diet containing 63 mg/kg of vitamin C and exposed to 37 mg/l of toxaphene. Arrows indicate protrusions of vertebral column. Photo by W. A. McAllister.

programs. This relationship suggests that the insecticide may have subtle, adverse effects on basic biological processes of fish in areas of toxaphene use.

In further studies, we determined that nutritional factors can influence the tolerance of fish to toxaphene. Vitamin C, an essential dietary nutrient for fish, is involved in detoxication mechanisms in the liver and in collagen formation by hydroxylative enzymes. Inasmuch as these two hydroxylation processes might compete for vitamin C and cause decreased collagen, we attempted to determine the effects of toxaphene on the distribution of vitamin C in liver and bone in channel catfish fry.

The fry were exposed to toxaphene (0, 37, 68, 106, 218, and 475 ng/l) for 150 days. The fish were divided into three groups within each concentration, and each group was fed a diet with different amounts of vitamin C (63, 670, and 5,000 mg/kg). All toxaphene concentrations decreased backbone collagen in fish fed the low vitamin C diet, and the three highest concentrations of toxaphene decreased collagen in fish fed the 670 mg/kg diet, but only the highest toxaphene concentration decreased collagen in fish fed the diet containing 5,000 mg/kg of vitamin C. The incidence of spinal deformities decreased with increased dietary vitamin C, as did the effects of toxaphene on

mucous cells of the skin and gill cartilage. The effect of toxaphene on mucous cells could increase the susceptibility of fish to diseases, impair wound-healing processes, and compromise the ability of fish to respond to natural stresses. Our investigations indicate that availability of essential nutrients, such as vitamin C, in natural food sources must be considered when one interprets the biological significance of toxaphene residues in fish from a given environment.

Biochemical Indicator of Fish Growth Under Development. — Chronic toxicity studies with fish are expensive, high-risk endeavors, requiring from 10 to 12 months to conduct. Such studies include growth, reproduction, and survival of adults, and growth and survival of the offspring. As a consequence, there has been much interest in the development of alternative methods that provide similar information with less expenditure of time and effort. Therefore, we attempted to assess the possibility of using biochemical factors as indicators or predictors of growth and development in fish. Growth of fish is usually evaluated by measuring weight and length; however, biochemical changes due to toxic materials should, logically, occur before becoming evident as a reduction in growth. This approach was incorporated into our investigations of toxaphene.

We selected collagen and hydroxyproline concentrations in collagen for our studies because collagen is the major fibrous protein and component of the organic matrix of bone and other connective tissues in vertebrates, and functions as a structural support for these tissues. Fish continue to grow throughout their life and must have proper collagen formation to enable their backbone vertebrae to increase in size in proportion to growth. For normal growth and bone development to proceed, vitamin C is needed for collagen synthesis because it is an essential cofactor for the enzyme collagen hydroxylase. This enzyme catalyzes the hydroxylation of proline to hydroxyproline, which is an amino acid that is necessary for the structural integrity of the collagen matrix. However, if large amounts of the body's supply of vitamin C are utilized for the detoxication of a chemical, other essential processes that require vitamin C, such as collagen formation, may be severely restricted. Fish are especially vulnerable to such interference from chemical contaminants because they cannot synthesize vitamin C and must depend upon a finite dietary intake as a source. We have found that hydroxyproline and backbone collagen concentrations are sensitive biochemical

indicators of growth in fathead minnows, brook trout, and channel catfish exposed to toxaphene. Decreases in collagen and hydroxyproline concentrations occurred at least 30 days before changes in weight or length were evident. Similar results were observed in brook trout exposed to Aroclor 1254 and in fathead minnows exposed to the dimethylamine salt of 2,4-D. Results from these studies suggest that collagen and hydroxyproline measurements can be used as indicators and predictors of growth in fish to shorten chronic toxicity tests. Other biochemical processes, such as the ability to respond to stress, require vitamin C and could also be affected when large amounts of vitamin are used by the liver for the detoxication of organic contaminants.

The effect of toxic materials on collagen formation is not species specific. Through cooperative research with the Patuxent Wildlife Research Center, we found that chronic exposure of black ducks to toxaphene caused effects similar to those observed in fish, i.e., a decrease in both growth and backbone collagen. These changes in collagen metabolism in birds may also be related to the thin eggshell phenomenon, since collagen is also the main organic matrix around which mineral salts are deposited in the shells of eggs.

National Fish Monitoring Activities Relocated in Columbia. — The Fish and Wildlife Service became a participant in the National Pesticide Monitoring Program in 1967, with responsibility for measuring trends of pesticide residues in fish collected from the major watersheds across the nation. The program was designed to provide the minimum monitoring needed to establish baselines, detect residue trends over time, and identify potential pollution problems. Fish collections were made annually until 1975, when they were terminated to enable the Service to evaluate the monitoring activities and develop research-supported capabilities for chemical analysis of samples and interpretation of data. The analytical work group is now located at the Fish-Pesticide Research Laboratory, Columbia, Missouri, and is called the Aquatic Contaminant Monitoring Team. The Team will function with research elements of the Laboratory, regional environmental contamination evaluation specialists, and with other monitoring activities of the Service coordinated in the Washington, D.C., office. Team activities in 1976 have been limited to planning, staffing, and preparing analytical laboratory equipment and space.

In 1976 and 1977, the Team will be involved in

two types of monitoring activities. The first approach is traditional and is designed to detect trends in contaminant residues in fish. Fifty of 100 designated stations divided among 12 major drainage systems in the United States will be sampled in alternate years. Three composite samples will be taken from each station for analysis of whole-body residues of heavy metals and organic chemical contaminants. Objectives of this approach are to distinguish general trends in use patterns and disposal of environmental contaminants, and to estimate their distribution in freshwater fisheries over an extended period of time. The samplings are useful in reflecting the impact of regulatory actions on selected chemicals, as well as providing laboratory scientists an opportunity to analyze the collections for new contaminants.

The second approach is designed to provide special, short-range investigative capabilities which are coordinated with the regional offices, the Fish-Pesticide Research Laboratory, and the Washington, D.C., office. Investigative monitoring will focus on local or regional contaminant problems and will require more intensive effort than can be provided by monitoring of trends. Three investigative monitoring projects have been carried through the planning phases, and collections have been partially completed for 1976. One such study concerns the impact of environmental contaminants on striped bass along the Atlantic coast. This study is an effort to determine the influence of organochlorine, PCB, and heavy metal residues on survival and development of striped bass progeny through the eighth day of development. Two other investigative monitoring projects are under way to (1) determine point sources of unexpectedly high DDT contamination along the Rio Grande in Texas, and (2) analyze lake trout from Lake Michigan to ascertain the extent of toxaphene and PCB contamination. These investigations should be nearing completion in the summer of 1977.

Dioxin Removal from "Herbicide Orange" Proved Feasible. — Last year, chemists at the Fish-Pesticide Research Laboratory discovered a purification process which may permit reclamation and domestic use of millions of dollars worth of "Herbicide Orange" which is now impounded by the United States Air Force. This herbicide cannot be used domestically because it was found to be heavily contaminated with dioxins. Chlorinated dioxins and related dibenzofurans are among the most toxic compounds known to man, yet they have been found in widely used chemicals, such as the wood preservative pentachlorophenol and

formulations of the herbicide 2,4,5-T. Even with present technology, trace amounts of dioxins are unavoidably formed during the manufacture of several of these types of chemicals. Little is known of the distribution of dioxins or dibenzofurans in the environment.

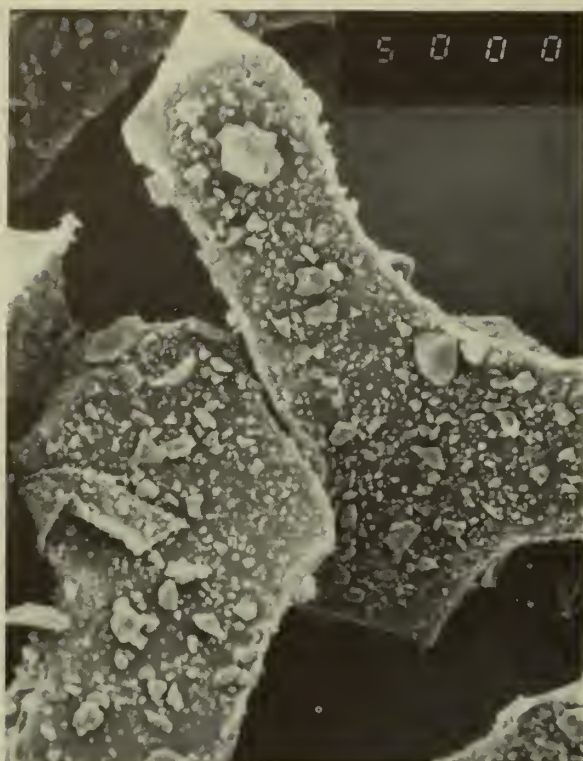
The purification process developed at the Laboratory is based on the strong adsorption of dioxins and related compounds by coconut charcoal; a patent on the process was filed by the Department of the Interior. As a result of the patent filing, a project was funded by the U.S. Air Force and jointly conducted by chemists from the University of Missouri and the Fish-Pesticide Laboratory for the cleanup of Herbicide Orange. When the feasibility of cleanup was demonstrated on a laboratory scale with columns of coconut charcoal, the most critical step in the process was the percolation rate of the herbicide through the charcoal bed.

Recently, the purification process for Herbicide Orange was satisfactorily demonstrated on a pilot plant scale by a private chemical company. Purification of the stockpile of 2.3 million gallons is now pending an environmental impact statement. However, an acceptable process for disposing of the contaminated charcoal is still needed.

We believe the purification process will permit reclamation of Herbicide Orange worth millions of dollars and may have potential for greatly reducing dioxin and dibenzofuran contamination in several widely used chemicals, thus preventing introduction of these toxic contaminants into the environment. The affinity of dioxins and related compounds for charcoal may have application to some kinds of cleanup of these or similar materials accidentally released into the environment.

Patent Filed on New Material for Dioxin Adsorption. — The Department of the Interior is filing a patent on a new adsorbent developed at the Fish-Pesticide Research Laboratory which may permit automated cleanup of environmental samples. The adsorbent consists of powdered charcoal which is held in place on reticulated polyurethane foam by strong interactions between the charcoal and foam surfaces. Charcoal-coated foam has high permeability and its use has already increased the efficiency and speed of analysis for some toxic industrial contaminants, including dioxins and dibenzofurans.

We are now testing foam-charcoal columns in conjunction with an automated gel permeation system for the cleanup of pesticides and industrial chemicals, which are present in many fish and



A scanning electron micrograph (300X magnification) of several pieces of shredded polyurethane foam with particles of AMOCO PX-21 charcoal adhering to the surface. The surface of the foam-charcoal complex was coated with a 400 Å gold film. Photo by J. A. White.

informed of the results of our analyses.

Great Lakes Fish Found to Contain Toxaphene.

— Toxaphene was recently detected in fish collected in the Great Lakes. This is one of the first reports of toxaphene residues in fish from this area. Over 50 samples of sport and forage fish were collected and analyzed at the request of the Twin Cities, Minnesota, Regional Office. All of the samples contained residues of toxaphene. The residues ranged from 8.1 $\mu\text{g/g}$ (ppm, whole body, wet weight) in a sample of lake trout from Lake Michigan to less than 0.2 $\mu\text{g/g}$ in several species collected from Lakes St. Clair, Erie, and Ontario. Residues of other contaminants found in the same fish included three polychlorinated biphenyls, *cis*- and *trans*-chlordane, *p,p'*-DDT, *p,p'*-DDD, *p,p'*-DDE, hexachlorobenzene, dieldrin, endrin, and heptachlor epoxide. Research with toxaphene at the Columbia laboratory has shown that this insecticide appears to have no effect on growth and reproduction of brook trout at concentrations as low as 40 ng/l (parts per trillion). Residues in brook trout exposed to 40 ng/l of toxaphene were about 0.6 $\mu\text{g/g}$, considerably less than the concentration of toxaphene measured in lake trout from Lake Michigan. Additional research is scheduled in fiscal year 1977 to confirm and further characterize the toxaphene residues.

Forest Insecticide Residues Detected in Fish After Spruce Budworm Control.

— Residues of three forest insecticides — Matacil, a carbamate, and Sumithion and Dylox, both organophosphates — were found in fish after the insecticide had been applied to several thousand acres in Maine to control spruce budworm. Sevin and Zectran were applied at the same time, but residues of these chemicals were not detected in fish. Over 80 samples of fish were analyzed during this cooperative project with the Forest Service, the Atlantic Salmon Investigations and the Boston Regional Office of the Fish and Wildlife Service, the University of Maine, and the State of Maine. Sumithion residues were found in all fish collected within 48 hours of its application. Concentrations of Sumithion residues in the fish ranged from 0.02 to 1.21 $\mu\text{g/g}$ and averaged 0.25 $\mu\text{g/g}$ (ppm, whole body, wet weight). In general, fish collected 24 hours after application of Sumithion contained higher residues than fish collected 48 hours after application. Matacil and Dylox residues were found in very few samples and were relatively low. For instance, Matacil residues ranged from 0.1 to 0.2 $\mu\text{g/g}$ and the only sample with a Dylox residue contained less than 0.1 $\mu\text{g/g}$. Toxicological studies

wildlife extracts. The tandem combination of this system and foam-charcoal columns will enhance separation of pesticides and industrial contaminants and is readily adaptable to automation of the cleanup of a wide variety of environmental samples.

Dieldrin Residues Cause Closing of Commercial Fishery in Iowa Reservoir. — Commercial fishing was closed in Coralville Reservoir, near Iowa City, when analyses at the Fish-Pesticide Research Laboratory revealed that channel catfish from the reservoir contained 0.86 $\mu\text{g/g}$ (ppm, whole body, wet weight) of dieldrin. We analyzed several samples of channel catfish at the request of Area and Region 6 Offices of the Service. The residues of dieldrin were high enough to lead us to suspect that they may affect channel catfish reproduction. In addition, we found relatively high concentrations of technical chlordane in the same samples. Because of the high residue of dieldrin, several thousand catfish scheduled to be stocked in Coralville Reservoir by the Service were stocked elsewhere. Also, officials of the State of Iowa closed this reservoir to commercial fishing after they were

with these insecticides are discussed elsewhere in this report.

Mirex Residues in Amphibians and Reptiles Collected in the Southeastern United States. — These animals were collected by personnel of the Auburn University Cooperative Wildlife Research Unit from areas having a history of repeated Mirex applications for eradication of the fire ant. The samples analyzed included toads, frogs, turtles, lizards, and snakes. Snakes contained the highest concentrations of Mirex, averaging $0.15 \mu\text{g/g}$ (ppm, whole body, wet weight), and the incidence of contamination was 83%. Other residues detected in these animals included heptachlor epoxide, *cis*-chlordane, several DDT isomers and metabolites, hexachlorobenzene, benzene hexachloride, toxaphene, dieldrin, endrin, and two polychlorinated biphenyls. In general, the residues measured in animals collected in this survey were slightly lower than those detected in fish from the same region.

GREAT LAKES FISHERY LABORATORY

The Role of DDE and PCB's in the Reproductive Failure of Lake Michigan Lake Trout. — DDE and PCB's are reported to be capable of affecting reproduction in fish at levels similar to those found in the eggs of adult spawning lake trout from Lake Michigan — up to 5 ppm of DDE and 8 ppm of PCB's in 1975. Previous work by the Great Lakes Fishery Laboratory and the Michigan Department of Natural Resources has shown that the hatchability and survival of young from contaminated eggs is generally good when they are held under standard hatchery or laboratory conditions. Little is known, however, about the survival of the contaminated fry when they are exposed to ambient levels of DDE and PCB in Lake Michigan — estimated at between 1 and 10 parts per trillion in water and about 0.01 ppm of DDE and 0.3 ppm of PCB's in plankton (wet weight).

In the winter of 1975-76, the Laboratory began studies to determine the individual and combined effects of DDE and PCB's on young lake trout from Lake Michigan. Eggs from spawning fish in the lake were incubated in the laboratory and the fry exposed for 160 days to DDE and PCB's (Aroclor 1254) in food and water at concentrations approximating those in the lake, and at levels 5 and 25 times higher than those in the lake. Another group of eggs from the lake was hatched and the fry reared as controls under conditions of no exposure

to DDE and PCB's.

Although studies are not yet complete, early observations are that the eggs from Lake Michigan lake trout generally hatched well (59% hatch); that the proportion of normal fry was high (97%); and that there was good survival of normal fry to swim-up (94%). Mortality among the young trout exposed to DDE— and particularly PCB's— was generally higher than in controls, although there appears to have been little correlation between mortality and the degree of exposure (dose). Additional observations on the growth and competitive fitness of the young trout are being made. Test factors include swimming endurance, predator avoidance, temperature preferences, respiratory metabolism, and biochemical characteristics.

At the beginning of the study, 200 newly hatched larvae from each collection of eggs were left unfed. We suspected that larvae from highly contaminated eggs of Lake Michigan lake trout would die before those from hatchery-produced eggs with low contamination. This hypothesis proved untrue, however, and it was found that the time to 50% mortality was 70 days (range 9-100 days) for starved larvae from Lake Michigan eggs containing 7.6 ppm PCB's and 4.8 ppm DDE, and 66 days (range 7-90 days) for starved larvae from hatchery eggs containing only 0.083 ppm PCB's and 0.003 ppm DDE.

Trends in Contamination of Great Lakes Fishes. — The need for, and effectiveness of, regulatory controls in reducing contamination of the Great Lakes is ultimately reflected in the types and amounts of contaminants present in fish from year to year. Past controls have been extremely effective in reducing average concentrations of DDT in fish from Lake Michigan and of mercury in fish from Lakes St. Clair and Erie. Nevertheless, both of these contaminants continue to exceed Government-imposed guidelines (action levels) in a few species and areas of the Great Lakes (particularly in lake trout from Lake Superior).

Of greatest concern currently are the continued high levels of PCB's in certain Great Lakes fishes — particularly salmonids from Lakes Superior, Michigan, and Ontario. For example, data developed by the Great Lakes Fishery Laboratory show that average concentrations of PCB's in adult fish taken from southeastern Lake Michigan during 1972-74 ranged from 5.2 to 5.7 ppm in bloaters, 10.4 to 12.2 ppm in coho salmon, and 12.9 to 22.9 ppm in lake trout. The data showed no decline in PCB levels during the 3 years. Thus, voluntary

restrictions in 1970-71 on the sale of PCB's did not result in a decline in PCB concentrations in the Lake Michigan fishes sampled. Although analyses are not complete on samples of fish collected during the fall of 1975, initial results for bloaters suggest a slight reduction in average PCB concentrations. An additional year of sampling, however, will be required to determine whether these results represent the start of a downward trend.

Also of concern are the continued elevated levels of dieldrin in Lake Michigan fishes. Concentrations of this pesticide in the Lake Michigan fishes mentioned above have ranged between 0.1 and 0.3 ppm since the late 1960's with no evidence of a decline. The production and sale of aldrin and dieldrin were banned in 1974, and we anticipate this action will soon be evidenced by a decline in average dieldrin residues in the fish.

Cooperative studies completed in 1975 by the International Joint Commission's Upper Lakes Reference Group disclosed that although PCB's, DDT, dieldrin, and mercury are the major contaminants of fish in Lakes Superior and Huron, several other compounds such as lindane, chlordane, chlorobenzenes, octachlorostyrene, heptachlorepoxyde, naphthalene, phenanthrene, toxaphene, and phthalates are also detectable in certain species and areas of the two lakes. The significance of the presence of these compounds in fish is unknown, but the need for continued surveillance to detect possible future increases in their concentrations is strongly indicated. Recent reports of Mirex in Lake Ontario fish at concentrations in excess of food guidelines add further support to the need for programs capable of detecting and controlling the buildup of toxic substances in the Great Lakes.

Effects of Contaminants on the Biochemistry of Lake Trout. — Studies were completed on the utility and sensitivity of allantoinase (an enzyme important in nitrogen catabolism) as an indicator of chronic effects of contaminants on lake trout. Contaminants under investigation were mercury, cadmium, lead, copper, DDT, and PCB's. Exposure of allantoinase in vitro to inorganic mercury showed that the enzyme extracted from acetone powder is about 100% active up to 20 ppm of mercury (Hg^{++}), above which the activity drops suddenly. At 30 ppm of mercury, the enzyme is 95% inhibited. The concentrations of metals at which 50% inhibition of allantoinase occurred were as follows: 0.21 ppm of lead (Pb^{++}), 0.67 ppm of cadmium (Cd^{++}), 0.63 ppm of copper (Cu^{++}), and between 20 and 30 ppm of mercury. On the basis of

molar concentrations, allantoinase is most sensitive to lead and least sensitive to mercury. Allantoinase was not affected by DDT or PCB's in vitro at concentrations up to 10 and 7 ppm, respectively.

Twenty lake trout, previously exposed for 28 weeks in the Laboratory to low levels of PCB's (0.1 ppb) in water, accumulated 2.6 ppm of PCB's in the liver, which had a mean allantoinase activity of 0.168 ± 0.0212 (\pm SE) $\mu\text{mol product (min)}^{-1}$ (mg protein^{-1}) compared with 20 control fish with a mean of 0.119 ± 0.0155 . This apparent activation of the enzyme by PCB's is significant at the 90% confidence level.

Allantoinase activity in the livers of lake trout from Lake Michigan was significantly higher than in similar samples from Lake Superior. Livers of large lake trout (larger than 500 mm) from Lake Michigan contained 21 ppm of PCB's, 4.7 ppm of total DDT, and 0.94 ppm of mercury, compared with 4.5 ppm of PCB's, 1.9 ppm of total DDT, and 0.69 ppm of mercury in the livers of Lake Superior fish. We also observed that allantoinase activity was negatively correlated with body length for fish from Lake Michigan, whereas no correlation was observed for fish from Lake Superior.

It appears that PCB's, DDT, and mercury, possibly acting synergistically with other contaminants, may be the cause of decreased allantoinase activity in large Lake Michigan lake trout. The significance of this reduction for survival of the fish is not known. In vitro assays, including kinetic data, provided some indication of the mechanism and relative toxicity of the different metals. However, the use of allantoinase as a short-term indicator of chronic effects now appears to have little potential.

PATUXENT WILDLIFE RESEARCH CENTER

Brown Pelicans in South Carolina Increase in Number, Resume Normal Reproduction in Wake of DDE Decline. — In 1976, brown pelicans in South Carolina numbered 2,500 breeding pairs, a substantial increase from the 1,116 pairs present in 1970, when only 945 young were fledged. Populations in the pre-DDT era have been estimated at 6,000 pairs, with an annual production of approximately 7,200. The 1976 population, although still less than half the number in the historic colonies, now has the potential to increase to the limits of the present-day habitat and food supply.

A long-term study, undertaken jointly with staff

of Cape Romain National Wildlife Refuge, recorded the upward trend during the same 8-year period that showed drastic decline of DDE in eggs of the nesting birds. Reproductive success increased as the population increased, although flooding of nests in 1972 and 1974 produced temporary setbacks.

Shell thickness increased 8% from 1969 to 1975 but was still 10% below the pre-1947 mean. Paralleling these changes, DDE residues in eggs declined from an average of 5.45 ppm in 1969 to 1.30 ppm in 1975.

Brown pelicans are among the species most sensitive to DDE-induced shell-thinning; the dramatic improvement in breeding success that paralleled the decline of DDE completes the study and validates the evidence that implicated DDT in the reproductive problems of this species.

Although DDE is the primary shell thinner, dieldrin and PCB's present in the eggs may have affected embryo survival or other aspects of reproduction. Dieldrin residues declined from 1.16 ppm in 1969 to 0.36 ppm in 1975 and so may have contributed to the overall improvement in population. PCB's, in contrast, were 6.11 ppm in 1969 and 6.24 ppm in 1975, fluctuating between 5.25 ppm and 7.51 ppm in the intervening years.

Nest Success of Texas Brown Pelicans. — Before 1920 the Texas coast supported a population of 5,000 brown pelicans. In 1963 the remnant population numbered no more than 100, and since 1970, fewer than 50 pelicans have been observed during the breeding season. Fewer than 30 were counted in 1976. Reproduction has been notably poor during these years, and recruitment of birds from Mexico has failed to compensate. Nest success was better in 1976 than in any year since 1963 — 16 young fledged from nine nests, a reproductive rate sufficient to maintain a population.

The full cause of the poor reproduction cannot be determined, but it seems probable that chemical contamination of the environment was a contributing factor. Shell thickness in 1961 was 15% below the pre-1947 measurements, 11% below in 1970, 9% below in 1974, and 7% below in 1976. Increasing shell thickness in these years suggests the possible beginning of improved reproductive success. Eggs were not analyzed in the earlier years. In 1970, however, DDE in eggs measured about 3 ppm and by 1974 about 1 ppm. PCB's declined from 10 ppm in 1970 to 3 ppm in 1974.

Brown Pelicans Prosper in Florida; Problems Beset Birds Transplanted to Louisiana. — Surveys of Florida pelicans in 1969 showed much less shell



Residues of DDE in eggs of brown pelicans have declined during the last several years. Improvements in breeding success occurred during this period, validating the evidence that implicated DDT in the reproduction problems of this species. Photo by J. O. Keith.

thinning and lower organochlorine residues than in South Carolina pelicans. Eggshells from the Atlantic Coast were 9% thinner than in the pre-DDT era and Gulf Coast eggshells were 7.5% thinner. Little change occurred by 1974, the last sampling period.

Mature brown pelicans were extirpated in Louisiana in the 1960's and did not return. Restoration efforts began in 1968 by annual transplants from Florida colonies. The pelicans began breeding in 1971, and success seemed assured.

The subtler effects, however, suggest that pollution of the Louisiana ecosystems may slow or halt improvement. The most critical aspect is the steadily declining thickness of eggshells, which averaged 0.517 mm in 1971 but dropped to 0.480 in 1975. This drop represents a 7.2% thinning from 1971 and is 13.4% below the pre-1947 norm. Shell thickness was 0.494 mm in 1976, a slight improvement. DDE levels in eggs averaged 1.3 ppm in 1972 and 1973, 0.78 in 1975. Dieldrin measured 0.45 ppm in 1972, 0.64 ppm in 1973, and 1.08 in 1975. Endrin (0.50 ppm) was also present in 1975. In that year, a number of adult birds died in Louisiana with lethal and near-lethal levels of endrin in their brains. Adult mortality among long-lived, late-breeding birds such as brown pelicans can adversely affect population survival, compounding the ill effects.

New Endrin Problems Identified. — Recent work suggests that the insecticide endrin is more

dangerous to birds than generally believed: (1) White pelicans dying in the Tule Lake area of California proved to have ample amounts of endrin in their brains to account for death. (2) Secondary poisoning with endrin was demonstrated both in the field and laboratory. Hawks soon died when fed endrin-killed prey. (3) Brown pelicans of the endangered Louisiana population had endrin as well as dieldrin, toxaphene, and other insecticides in their brains at death. These chemicals may have been the cause of death of some Louisiana pelicans, both white and brown. (4) Endrin was present in nearly all eggs of brown pelicans in Louisiana. The amounts ranged from zero to 2.3 ppm in 1974 but were usually around 0.5 ppm (wet weight). The significance of these levels for hatchability is not known. The egg residues prove, however, that Louisiana pelicans commonly take in endrin and hold it for some time.

Endrin residues in pelican eggs and lethal levels of endrin in pelican brains suggest that pelicans do not lose endrin as rapidly as some animals do. Rats lose half of their intake of endrin within 2 to 4 days, metabolizing and excreting it rapidly. Experimental quail, pheasants, and mallards can break down and excrete endrin well enough to live for at least a year or two with 1 ppm in the diet. Some mallards can tolerate surprisingly large amounts of endrin in the diet, which explains why kills of waterfowl by endrin have rarely, if ever, been reported from the field.

Heavy Metal Residues in Eggs of Black-crowned Night Herons Are Measured. — Measurable concentrations of seven heavy metals were detected in 48 night heron eggs from five Atlantic Coast States. Arsenic concentrations were significantly greater in samples from South Carolina, Maryland-Virginia, and Massachusetts than in samples from Louisiana and Florida. Mercury concentrations in samples from Massachusetts were higher than in samples from Louisiana, Florida, and Maryland-Virginia. Elevated levels of arsenic and mercury at some localities probably reflect local contamination. Mercury was present in some eggs at levels near those causing impaired reproduction in ring-necked pheasants. Mean concentrations of cadmium, chromium, copper, lead, and zinc did not differ significantly among localities — they probably represent background levels.

Organochlorine Residues in Eggs of Anhingas and Wading Birds. — Eggs from more than 1,300 clutches of anhingas, herons, ibises, and related species were collected from 50 localities in the eastern United States during 1972 and 1973 and



Black-crowned night heron at its nest. Residues of heavy metals in night heron eggs collected along the East Coast reflected local contamination. Photo by K. A. King.

were analyzed for organochlorines. Organochlorine residues, including mirex, were more frequently found in eggs from the Great Lakes region than in eggs from other areas. Eggs from coastal colonies in the Northeast had the second highest frequency of occurrence of chemical residues, and eggs from coastal areas of the Gulf of Mexico had the lowest. DDE was present in 96% of the eggs analyzed and PCB's in 61%. Other compounds detected were DDD, DDT, dieldrin, *cis*-chlordane, *trans*-nonachlor, and hexachlorobenzene.

Eggshell thinning occurred in anhingas from Louisiana and Mississippi (-7.5%); great blue herons from Florida (-5.5%) and the Midwest (-6.8%); wood storks from Florida (-8.9%); and black-crowned night herons from New Jersey (-12.3%), Massachusetts (-9.3%), New York, Rhode Island, and Connecticut (-7.1%), Ohio and Michigan (-5.6%), and Florida, Georgia, and South Carolina (-4.6%).

Wading Birds as Indicators of Environmental Quality. — The hypothesis that wading birds are indicators of coastal environmental quality and can be used as the basis of a biological monitoring program was subjected to field tests on the Atlantic Coast in 1975 and 1976. Earlier, Patuxent studies had shown that wading birds clearly depicted the chemical contamination of the coastal ecosystem and showed the need for extending the research to encompass problems beyond those introduced by



White ibis, adult and young on nest. Photo by K. A. King.

pesticides.

Early results have been most promising, but several years of study will be required to measure the natural variability in colony size, location, and species composition as a background against which to evaluate changes produced by man-made disturbances.

Eight teams of investigators located and censused 198 colonies along the Atlantic Coast from Maine to Florida. Fourteen species, including over a quarter million breeding birds, were censused. The number of species in colonies ranged from 1 to 11. Colonies with one or two species increased, and colony size decreased, from Florida to Maine.

Five teams of investigators studied the reproductive biology of nine species in 13 colonies. Mean clutch size, the percentage of nests in which one or more eggs hatched, and the overall percentage of eggs that hatched differed among colonies for some species, but no latitudinal gradient was found in any of these parameters for any species.

Identification of the portions of the environment of crucial importance to the different species was



Wading bird colonies of the Atlantic Coast are concentrated in areas of increasing population and industrial development. Investigations now under way show these birds to be effective biological indicators. The map shows locations of the 198 colonies found in the first year of the study.

approached through an analysis of feeding behavior. Feeding sites of the great egret, snowy egret, and Louisiana heron, located near Beaufort, North Carolina, were described by eight environmental variables: elevation, cordgrass (*Spartina alterniflora*) height, cordgrass density, water depth,



Young osprey at its nest on the Potomac River, Maryland. Biologists from the Patuxent Wildlife Research Center have studied the effects of environmental contaminants on the reproduction of ospreys on the Chesapeake Bay and surrounding areas since 1968. *Photo by J. R. Maestrelli.*

water conductivity, water hardness, water turbidity, and water temperature.

Analysis of these variables and of the differences in habitat use by the different species will constitute the second phase of these studies.

Chemical Residues in Bald Eagles, 1973-74. — Eighty-six bald eagles found dead or dying in 24 states all contained DDE, and all but two contained PCB's. Seventy-five contained dieldrin, four at levels high enough to suggest death from dieldrin poisoning. Heptachlor and one or more chlordane residues were present in more than half the birds. Mirex was present in 28. Illegal shooting accounted for 25% of the deaths, a smaller percentage than in the past. Two eagles died as a result of fights with other eagles; one flew into the propeller of a plane; six drowned; and three were killed by trappers after capture in muskrat traps.

Organochlorine residues remained high in eagle carcasses. Median levels in the 2 years were 12 and 7 ppm for DDE; 0.7 and 0.6 ppm for dieldrin; 23 and 10 ppm, PCB's; 0.7 and 0.25 ppm, mirex. Highest level of DDE was 110 ppm; of dieldrin, 14 ppm; of PCB's, 820 ppm; and of mirex, 8 ppm.

Dieldrin Toxicity Enhanced, Lethal Brain Levels Lowered, by Presence of Other Chemicals. — Eagles found dead in the field frequently contain residues of dieldrin in their brains just below the levels known to be in the lethal range, and in these cases a great many other chemicals usually are present in substantial but sublethal amounts.

An experiment to compare the effects of an

aggregation of chemicals with those of dieldrin alone showed that the effects of a combination of chemicals were additive; in fact, the presence of other chemicals lowered the levels of dieldrin in the brains of dead birds. Chemicals in the mixtures were those most often encountered in eagles: PCB's, DDE, chlordane, DDT, heptachlor, and hexachlorobenzene.

Birds fed only dieldrin survived longest and had the highest levels of dieldrin in their brains. Those fed the mixtures survived shorter periods of time and had lower levels of dieldrin. None of the other chemicals approached diagnostically lethal levels determined for them in other studies. Percentages of lethal levels of each chemical present, however, added up to essentially 100%.

Bald Eagles in Maine Have Continuing Pollutant Problems. — Eggs of bald eagles, collected primarily from unproductive nests, were used to monitor levels of pollutants and to determine the effects of these pollutants on reproduction. Productivity of Maine bald eagles has been low for many years. Levels of DDE in eggs collected there in 1974 and 1975 had not declined from the levels found in eggs collected in the late 1960's, even though use of DDT has been virtually discontinued there since 1970. Dieldrin levels in Maine eggs appear to be declining while PCB levels appear to be increasing, and most eggshells continue to be considerably thinner than normal.

A preliminary study was conducted to determine the source and trends of pollutant levels in foods of Maine bald eagles. Fish samples collected in 1974 generally contained higher levels of PCB's but lower levels of DDE than were found in 1966. Gulls collected in 1966 contained much higher levels of pollutants than were found in fish, indicating that birds may be an important dietary source of pollutants for the eagles and their eggs.

DDE Strikes Barn Owl Reproduction; Dieldrin Does Not. — DDE at 3 ppm in the diet of captive barn owls caused shell thinning, failure to hatch, and death of young. Only six young fledged from 114 eggs laid (5.3%) by adults fed DDE. These birds lost clutch after clutch. In contrast, almost 50% of the eggs laid by control birds produced surviving young. Dieldrin at 0.5 ppm in the diet did not produce the same effects as DDE; hatching and fledging were as good as those of controls. Owls fed DDE laid eggs that averaged 24% thinner shells than eggs of controls.

Residues of Environmental Pollutants Low in Chesapeake Bay Canvasbacks. — Canvasback ducks collected from Chesapeake Bay during the

winters of 1975 and 1976 contained low levels of organochlorine compounds. DDE (0.10-6.3 ppm) and PCB's (<0.5-14 ppm) were detected in almost all samples. Dieldrin occurred in 14% of the samples. Residues of organochlorines in most canvasback eggs were below levels known to impair reproductive success in birds.

Cadmium levels in canvasback kidneys ranged from 0.11 to 9.1 ppm. Experimental studies with mallards have shown that birds on a chronic dietary dosage of 2 ppm cadmium accumulated levels in the kidneys similar to levels found in wild canvasbacks.

Canvasback livers contained lead residues ranging from <0.04 to 1.9 ppm. A few of the birds were exposed to elevated levels of lead, but the majority reflected only background levels.

Lead-iron Shot Reduces Lead Toxicity to Mallards. — An experimental lead-iron shot containing 40% lead was less toxic than commercial lead shot to mallards fed a whole corn diet. Higher mortality occurred in ducks dosed with lead shot compared with ducks given lead-iron shot containing comparable amounts of lead. One #8 lead shot caused 35% mortality in 4 weeks, and higher amounts of lead caused nearly 100% mortality. Ingestion of one or two #4 lead-iron shot caused only 5% mortality during a 14-week period. Ducks dosed with 5 lead-iron shot suffered 45% mortality compared with 50% mortality for those given 16 shot.

In other studies, the toxicity to mallards of lead-iron shot composed of 40 to 60% lead was compared with the toxicity of commercial lead shot and commercial steel shot. Mortality and body weight were directly related to percentage of lead in the dose. Survival time, packed cell column, and hemoglobin levels were inversely related to the amount of lead. Five #4 shot composed of no more than 40% lead were relatively nontoxic to captive game farm mallards fed a diet of corn. (This study was carried out under contract to the Illinois Natural History Survey.)

Hazards of Multichemical Exposure Explored. — The possibility of interactions between chemicals is much feared but little understood. Results of several studies suggest the hazards may be real but the problems complex:

Chlordane and endrin add up in brain to cause death: Bobwhites were given nonlethal doses of chlordane followed by lethal doses of endrin. Others were given endrin alone. The residues of endrin in the brains of bobwhites that died after receiving both chemicals averaged 38% lower than residues in birds that died of endrin alone. The



Nestling barn owls in a duck blind on the Potomac River, Maryland. Studies with captive barn owls have shown them to be sensitive to the effects of DDE. Photo by J. R. Maestrelli.

chlordane components clearly had an additive action with endrin.

DDE increases susceptibility to parathion; chlordane reduces it: Adult male coturnix were pretreated with DDE or chlordane for weeks before being challenged with parathion. DDE increased the mortality from parathion, but chlordane had a protective effect. The two chlorinated hydrocarbons apparently had different effects on liver enzymes that affect the action of parathion.

Low levels of methyl mercury intensify the action of carbofuran: Explorations of interaction between methyl mercury and carbofuran, a commonly used pesticide, showed that preexposure to low levels of mercury increased the effects of carbofuran on the brain. The same result did not occur with parathion, a chemical of the organophosphate group.

Impact of DDT Spraying in 1974 for Control of Tussock Moths. — During June and July of 1974 more than 400,000 acres of forested land in northeastern Oregon, southeastern Washington, and adjacent areas of Idaho were sprayed with DDT for control of the tussock moth. The Fish and Wildlife Service cooperated with the U.S. Forest Service to investigate the impact of this single spray on raptorial and insectivorous birds that nest on treated areas. Three hundred nest boxes were set out in and adjacent to spray areas to attract nesting American kestrels. Mountain bluebirds and common flickers as well as kestrels readily nested in the boxes.

Levels of DDT and its metabolites built up in kestrels after the aerial application of DDT. DDT residues in blood of birds from the spray areas increased almost immediately after spraying and



Captive kestrels at the Patuxent Wildlife Research Center are used in studies to assess the effects of environmental contaminants on birds of prey. Knowledge obtained is applied to the peregrine falcon and to other comparatively rare species. *Photo by L. C. Goldman.*

continued to increase the next year. Residues also increased slightly in birds on adjacent nonspray areas the year after spraying. Residues in eggs of kestrels, bluebirds, and flickers followed the same pattern observed for kestrel blood. A preliminary evaluation indicates that residues in blood of kestrels declined during 1976 as compared with 1975, but were still about fivefold higher than prespray levels. Kestrel eggshells from the spray areas were 10% thinner than eggshells from nonspray areas, although production of fledged offspring was almost identical on spray and nonspray areas.

Studies will continue with the kestrel population in the future. Additional studies will be concerned with accipiter hawks, which also nest in the area. Rapid population declines, thin-shelled eggs, and reduced productivity have been observed in populations of Cooper's and sharp-shinned hawks. These bird-eating hawks may be more vulnerable to DDT exposure than the more insectivorous species studied thus far.

Effects of New Chemicals on Wildlife in Western Forests. — Pilot studies for control of western spruce budworm and tussock moth included tests of effects on wildlife of four of the newer chemicals used to control forest insects: Dylox, Sevin, Dimilin, and Orthene.

Dylox and Sevin-4-oil, which were studied in spruce budworm areas, had no observable deleterious effects on nest success or population abundance of forest birds, and no dead birds were found in intensive searches. There were nine study plots ranging in size from 1,000 to 2,000 acres; three plots were untreated and three each were treated with one of the two chemicals. Thrushes, woodpeckers, flycatchers, swallows, house wrens, sparrows, juncos, and warbling vireos comprised the majority of the nesting population. Brain cholinesterase depression, which measures the effects of chemicals of the types used in these treatments, showed little overall change. However, during the first day or two after both Dylox and Sevin sprays, significant depression occurred in a few birds of each of several species. The full significance of such changes in terms of susceptibility to predation or ability to obtain food remains to be evaluated.



Sapsucker nesting inside an aspen tree. Breeding success of nesting birds is an important indication of the effects of forest insecticides on birds that breed in western forests. A tubular device facilitates viewing the nest contents. *Photo by A. W. Shultz.*

Sevin, Dimilin, and Orthene were tested in tussock moth areas. Neither Sevin nor Dimilin adversely affected populations or reproduction of forest birds. As in the spruce budworm areas, however, brain cholinesterase depression was measured in a few birds shortly after treatment with Sevin.

Orthene, however, had indications of adverse effects on birds. Breeding bird censuses showed an estimated decrease of six pairs after treatment on one plot, although not on another. Several birds were found tremoring or with other signs of organophosphate poisoning. Brain cholinesterase activity was significantly depressed in most species. Although overall population effects could not be fully evaluated from this single study, there is sufficient evidence of hazard to indicate that chemicals other than Orthene should be used for aerial control of forest pests.

New Research Evaluates Impact of Petroleum Hydrocarbons on Birds. — Major oil spills, which oil and kill thousands of birds and disfigure beaches, have stimulated public concern and resulted in much effort to clean and salvage oiled birds. Spectacular accidents, however, contribute only a small percentage of the 5 million metric tons that are estimated to be the annual global input of oil to the oceans. The bulk of the polluting oil results from “normal” operations.

Little attention has been given to the effects of chronic low-level oil pollution or to the less easily observed effects of major spills. Research initiated in 1976 is directed toward understanding the impact of such exposure through a series of studies of the ecological, physiological, and toxicological effects of oil on birds. Results obtained in 1976 suggest the possibility of real hazards:

Trace amounts of oil on mallard eggshells killed developing embryos in a first-step simulation study of the possible effects of oiled plumage on eggs of incubating hens.

Experimental studies involving 350 eggs showed a direct relationship between the amount of oil and mortality of the eggs. No embryo survived application of 50 μ l; 2% survived 20 μ l; 12% survived 10 μ l; and 45% survived 5 μ l. Eighty-eight percent of the untreated control eggs survived. Oil was applied to the side of the egg, just away from the air sac, when embryos were 8 days old. Oil was taken into the shell almost instantaneously and did not spread over the surface. As a double check on whether the action was toxic rather than the result of blockage of gas exchange through the shell, two additional groups were tested. In one group, in

which eggs were treated with 50 μ l of propylene glycol, 80% hatched. In another group, in which eggs were treated with 50 μ l of a mixture of nine paraffin compounds found in crude oil, 72% hatched. Dosage was carried to an even lower level in a second experiment. Application of 1 μ l of oil to each of 50 eggs resulted in 68% survival compared with 98% among 50 untreated controls. One microliter of oil represents approximately 0.02 parts per million.

Susceptibility to toxic effects of egg oiling was greatest at early stages and diminished with age.

In a study involving 280 mallard eggs, 5 μ l of oil were applied to eggs at 4-day intervals, beginning the 2nd day of incubation. The result was 13% survival when the oil was applied to the youngest group, compared with 80% for controls. Most embryos died within 48 hours of oiling.

Eider embryos were killed by trace amounts of oil applied to shells, validating cross-species comparisons of such effects.

In a test involving 200 fertile eggs of mixed ages, 69% of the embryos survived 20 μ l and 92% survived 5 μ l. Ninety-six percent of the untreated controls and of those treated with 20 μ l propylene glycol hatched. The better survival of eider embryos than of mallard embryos appeared to be the result of treating eggs of mixed ages; most eider eggs were more than 8 days old — the age at which mallard eggs were treated.

Mallard ducks survived dosages of 100, 1,000, and 10,000 ppm oil in diets for 6 months and 25,000 ppm for 2 months in a small pilot study (16 birds). Egg production, however, declined markedly as dosage increased. Those fed 25,000 ppm also lost weight despite normal food consumption.

Vanadium, a contaminant that can reach 50 to 1,400 ppm in crude oil and that may also enter the environment as a result of disposal of processing wastes, impaired fat metabolism in adult mallards at dietary dosage of 1 to 100 ppm.

Blood cholesterol in drakes increased with dosage increase. Nonlaying hens were not affected. Laying birds, however, which normally show a pronounced decrease in blood cholesterol associated with transport of fat to eggs, failed to show this decrease. In pilot studies, laying ducks that had oil mixed into their diet laid fewer eggs than normal.

More than 400 clutches of seabird eggs have been collected for contaminant analysis from more than 15 Alaskan sites where population surveys are under way. Eighteen species are included thus far.

Development of chemical analytical methodology is approaching completion of the first phase.

Extraction, separation, and identification of oil in spiked liver tissues and feed at 20 ppm have been successfully accomplished.

Analysis of animal tissues for oil is difficult because of the very large number of compounds involved, the metabolic changes of these compounds that may occur in warm-blooded animals, and the presence of natural hydrocarbons in animal tissues. Hydrocarbons in petroleum have such a wide range of molecular structure and molecular weights that no presently available method of analysis provides an accurate assessment of total petroleum contamination when considering all possible oil-contamination incidents.

Generalizations have been made concerning methods for distinguishing between petroleum hydrocarbons and recent native hydrocarbons in living tissue but, in fact, only a very few terrestrial and marine species from only a few geographical localities have been analyzed for their natural hydrocarbons.

SOUTHEASTERN FISH CULTURAL LABORATORY

Field Tests of a Growth Regulator Insecticide. — We completed part of a field study to evaluate the

biologic effects of Dimilin (a potential mosquito larvicide) on major pond organisms and residue dynamics in largemouth bass, freshwater clams, sediment, and water (residue data to be completed by Thompson-Hayward Company). Ponds were sprayed with either 0, 1X, or 4X the recommended application rate of Dimilin (0.03 pound active ingredient per acre), four times at biweekly intervals, and serial samples were taken for 70 days. Fish and clams were not affected but daphnid populations were inhibited, as indicated from counts (per m³) of 1,460, 217, and 6 after 0, 1X, and 4X application rates, respectively. Densities of dipteran larvae similarly declined in benthic and periphyton samples. Gastropods were numerous on plate samplers but scarce in benthic samples after application. Numbers of oligochaetes more than doubled in control ponds but declined in ponds sprayed with Dimilin. Results of this field test will help in developing guidelines for Dimilin applications.

Water Contamination from an Unusual Source.

— A source of contamination in water supplying hatching tanks that killed striped bass fry last spring was traced to Aroclors in the laboratory's compressed air supply. These PCB's were commonly used in oil-type compressors. Another potential source of water contamination was traced to Aroclors in cutting oil used in threading and cutting steel pipes.

Coastal and Anadromous Fish

ATLANTIC SALMON INVESTIGATIONS

Because little is known about the routes and rates of seaward migration by young Atlantic salmon (smolts), a telemetry study was conducted on the Penobscot River, Maine, in 1975 and 1976. Tiny ultrasonic transmitters were inserted into the stomachs of hatchery-reared smolts, before the fish were stocked in the Penobscot at intervals between mid-April and early June. The sonic signals from the fish were detected by a boat-mounted hydrophone. In each year, the definite downstream movement of smolts began on May 10, and appeared to be triggered by photoperiod and water

temperature. The smolts traveled downstream both day and night, stayed mostly in the main current and channel, remained within 2 or 3 m of the surface, and moved without hesitation from fresh to salt water.

The telemetry study was extended in 1976 to include adult salmon returning from the sea and migrating upstream in the Penobscot River. Large fish were trapped at a fishway, and miniaturized radio transmitters were inserted into the stomachs. The fish were released and tracked by receivers in aircraft and boats. Some fish held position for as long as 20 days below dams equipped with fishways; others ascended fishways and then



A fresh-run adult Atlantic salmon being tagged at the Union River fishway in Maine in July 1976. The fish will be transported to a brood stock holding pool at the Craig Brook National Fish Hatchery, East Orland, Maine, for spawning in the fall. *Photo by M. M. Campbell.*

descended them; and some moved upstream and remained there. Most movement occurred at or near sundown.

Postspawning adult Atlantic salmon, known as kelts, generally remain overwinter in the spawning river before returning to the sea. Only a small percentage survive to spawn again. There is growing interest, however, in possibilities for increasing the survival of kelts that are trapped and held as hatchery brood stock. Their return to salt water and the resumption of feeding after months



A fresh-run adult Atlantic salmon being released into a brood stock holding pool at Craig Brook National Fish Hatchery, East Orland, Maine. The salmon was trapped at the Bangor Dam fishway on the Penobscot River in June 1976. *Photo by M. M. Campbell.*

of pre- and post-spawning fast is the subject of a Service-sponsored study at the University of Maine. For kelts held in captivity, there appears to be a need for careful meshing of increasing photoperiod in the spring with increasing salinity to stimulate appetite and feeding. An imbalance of light and salinity may inhibit feeding, and kelts that lose about 50% of their prespawning weight usually die.

Some Atlantic salmon streams were included in the 3.5 million acres of forest land in Maine sprayed with insecticides in June to control a spruce budworm infestation. Concurrent studies in the laboratory and field indicated that there were few adverse effects directly on salmon and brook trout, but there may have been sharp reductions in the stream invertebrates on which the fish feed.

EASTERN FISH DISEASE LABORATORY

Enteric Redmouth Disease (ERM). — This bacterial disease of salmonids, originally found in Idaho in the 1950's, has since been found in all areas of the United States and parts of Canada. Some of the outbreaks undoubtedly have resulted from inter-regional transport of infected fish.

Recent comparisons have shown that eastern and western strains of the bacterium were serologically indistinguishable. Morphological and biochemical tests were developed for rapid and accurate identification of ERM bacteria. In addition, fluorescent antibody techniques (FAT) were developed for identification of the ERM bacterium in infected fish. For the FAT, a fluorescent dye is coupled to antiserum specific for the ERM bacterium. The ERM bacteria are specific targets for the antiserum with its fluorescent dye. As a result, in the presence of specific antiserum, bacteria fluoresce brilliantly when viewed with microscopes having an ultraviolet light source. Older diagnostic procedures required 2 to 3 days to complete, but the new FAT procedures require only 1½ hours.

A New Trout Herpesvirus. — This herpesvirus was isolated from rainbow trout brood stock that had sustained abnormally high mortality after spawning. Testing has shown that the virus will grow only in rainbow trout cell cultures. Similarly, injected virus killed young rainbow trout, whereas brook trout, brown trout, and Atlantic salmon survived. Japanese investigators have found a similar, if not identical, virus killing young kokanee salmon, and a joint effort with them has resulted in

publication of a *Fish Disease Leaflet* (No. 44) describing the virus and its effects on fish. Major herpesvirus outbreaks have occurred at two places in Japan, but thus far only at the Winthrop National Fish Hatchery, Washington, in North America. Cleanup operations were put into practice, and surveys are being made to learn of other possible occurrences of the virus. The virus must be grown at temperatures lower than those normally used, and prolonged contact with cell cultures is required to insure its detection. Rabbit antiserum has been prepared against the new herpesvirus, but it has only marginal potency.

FISH CONTROL LABORATORY

Registration of Fishery Chemicals. — A review of the chemicals used in fish culture and fishery management indicated that many have never been properly registered, even though some, such as formalin, have been in use for over 100 years. In 1972 only 13 of the priority fishery compounds had some form of registration. By February 1976, four of the existing registrations had been upgraded by the establishment of tolerances. One compound, rotenone, had received an approved label revision. Five of the originally registered compounds were being studied for reregistration under the new rules of the Federal Environmental Pesticide Control Act, and 5 new compounds have been registered for the first time, bringing the total number of compounds registered for fishery use to 18 as of February 1976.

Seven other compounds for use have been submitted to regulatory agencies, petitioning rulings or exemptions: TFM, formalin, Thanite, quinaldine sulfate:MS-222, malachite green, calcium hypochlorite, and quinaldine sulfate.

Included in an EPA reregistration schedule for all chemicals are copper sulfate, 2,4-D, Bayer 73, Casoron, rotenone, diquat, dibromide, endothall, and simazine. Four registered fishery chemicals — antimycin, sodium chloride, Terramycin, and TFM — have not been scheduled for review.

Rotenone and Masoten are also subject to Rebuttable Presumptions Against Reregistration (RPAR), an action which may be rescinded only if evidence can be presented showing that no hazard exists or that the risk can be reduced to such an extent that significant adverse effects are unlikely.

TUNISON LABORATORY OF FISH NUTRITION

Basic Characteristics of Biological Filter Operation in Salmonid Culture. — Biological treatment of salmonid culture water that simulates the natural purification of water in streams permits 100% reuse of the water. Purification processes occur at water-floc interfaces, wherein protected and stable flocs contain a varied population of living organisms ranging from bacteria to nematodes in numerous predator-prey relationships within a porous, cohesive community. Efficient purification of culture water occurs as a consequence of the metabolism of the fish wastes by floc organisms as flowing water passes around them. A series of biofilters provides protected environments for specific floc groups to efficiently degrade carbonaceous and nitrogenous wastes. In addition, the metabolic wastes of one floc organism become the food of another. Refractory organic wastes (mostly humic substances) persist, coloring the water without harming the fish. However, physicochemical treatment of the water with ozone and activated carbon removes these wastes and produces a clear water suitable for aquaculture. Two easily separable and disposable filter wastes, one liquid and one solid, are produced from the combined biological and physicochemical treatments.

Use of Fatty Acids as a Function of Melting Point. — Using fatty acids with melting points between -78° and $+56^{\circ}$ C as supplemental fat in addition to the basic essential fatty acid requirement, chemists at the Tunison Laboratory of Fish Nutrition determined that fatty acids with low melting points have no beneficial effect on growth of either trout or coho salmon, regardless of the resident water temperature, between 6° and 15° C (42° and 59° F). Contrary to expectations, short chain fatty acids and their triglycerides, which have extremely low melting points, inhibited growth of fish. The most pronounced effect was exerted by butyric acid and by its triglyceride, which at 1% of the complete feed inhibited growth by 50%. The order of growth inhibition was butyrate > acetate > hexanoate > octanoate > decanoate > corn oil, coconut oil, triolein, and linseed oil. Some of these short chain fatty acids are the ultimate oxidation products of polyunsaturated oils and therefore at least part of the toxicity of such oils that are old or have oxidized is caused by the presence of these fatty acids.

Although short chain fats have been reported to cause ketosis in mammals, these fish showed no evidence of ketosis when tested for plasma acetone. Starved fish and those fed zero carbohydrate (except as triglycerides) also gave no evidence of ketosis — in contrast to mammals, which often develop toxic levels of ketone bodies under similar conditions.

Important Minerals in Diets of Atlantic Salmon.

— Atlantic salmon require dietary phosphorus for optimum growth, feed conversion, and bone development; however, little is known about the value of phosphorus contained in various practical feedstuffs. An experiment completed during the year showed that salmon used phosphorus in meat-bone meal and phytin (the major form of the element in plants) 90 and 0% as effectively as the phosphorus contained in inorganic phosphate.

A study with diets containing soybean meal as a major source of protein showed that fry required supplemental calcium, magnesium, and potassium.

Amino Acids Critical to Nutrition of Atlantic Salmon. — Young Atlantic salmon were seen to require a unique balance of dietary amino acids, necessary not only for protein synthesis and normal growth but also for prevention of abnormally high mortalities similar to those generally experienced in cultural operations.

Further dietary studies showed that commercial soybean meal could replace most, if not all, fish meal in salmon diets, provided that five amino acids were added to simulate the amino acid balance in trout eggs. Further experiments demonstrated that various other amino acid mixtures, beyond these five, gave no further improvement — thereby indicating a “near-maximum effect” with the original five.

Enzymatic analyses showed that levels of the enzyme that degrades the amino acid arginine in various fishes of similar size, fed the same diet, were lowest in Atlantic salmon and brown trout, intermediate in brook trout, and highest in rainbow trout. Such enzyme levels may be directly related to the quantitative requirements of these fishes for dietary arginine.

Specially Processed Soybeans as a Protein for Salmon. — Experiments with coho salmon showed that full-fat soybeans given heat treatment could supply the bulk of the dietary protein in starter and grower diets if they contained 20 and 10% fish meal, respectively. Such soybeans also have potential for economical use in diets of Atlantic salmon.

Additional Heat Treatment Improves Soybean Meal as a Source of Protein for Salmon. —

Previous experiments suggest a fairly high potential for the use of commercial soybean meal (SBM) as a major source of protein in diets of Atlantic salmon. However, nutritional observations suggested that SBM may be currently underheated. Chemical binding tests with many different samples of SBM correlated very well with degree of heat treatment applied in the laboratory. Binding tests on many different samples of commercial SBM showed a wide variation in the range of heat treatments. Therefore, nutritional studies were conducted that confirmed that many samples of SBM were underheated, causing growth depressions of 20 to 30% in salmon. Parallel cooperative studies with poultry gave similar results. However, these initial studies measured responses under limited dietary conditions, which need to be expanded to determine the influence of various supplements of amino acids to SBM on the nutritional response to added heat treatment. If consistent results prove that the poultry industry (which exerts a powerful economic influence on the processors of soybeans) could benefit from additional heat treatment, as would fish culturists, it may be possible to effect changes in the processing of SBM that would benefit both groups.

WESTERN FISH DISEASE LABORATORY

Ozone Studies. — High-quality pathogen-free water is essential for the successful operation of hatcheries. Ozone treatment has potential value as a disinfectant for water and is currently being used, or is being considered, as a replacement for chlorine in municipal water supplies, sewage treatment, and nuclear power plant cooling systems. The effect of the chemical on fish pathogens and fish must be identified before its use becomes more widespread, to ensure protection of the fish resource.

A concentration of 0.01 ppm ozone inactivated enteric redmouth disease (ERM) and *Aeromonas salmonicida* (furunculosis) in 0.5 and 10 minutes, respectively, in phosphate-buffered distilled water. A residual of at least 0.05 ppm chlorine was needed to cause a comparable kill in 10 minutes. In soft lake water a chlorine residual of 0.1 ppm rapidly inactivated both pathogens but in hard water *A. salmonicida* was more resistant. Ozonation of the two lake waters at 90 mg O₃/h per liter (equivalent to a 0.01 ppm residual in ozone demand-free water) destroyed both pathogens within 10 minutes.

The ERM bacterium survived through 20 days at 20° C in either soft or hard lake waters, whereas *A.*

salmonicida survived for only 2 days. This indicates that disinfection of soft water might not be necessary for furunculosis, provided the hatchery intake reservoir allows a 1- to 2-day detention time. For ERM control, however, treatment would be necessary to remove this pathogen.

Under laboratory conditions, in phosphate-buffered distilled water, less than 0.01 mg/l ozone was required to kill the virus of infectious hematopoietic necrosis (IHN) within 30 seconds. Ten times this much chlorine (0.1 mg/l) was needed to destroy IHN virus within 30 seconds or infectious pancreatic necrosis (IPN) virus within 2 minutes.

In both soft and hard lake waters, ozone applied at the rate of 70 mg O₃/h per liter completely destroyed IHN within 10 minutes; however, exposure to 90 mg O₃/h per liter caused a marked reduction but not total kill of IPN virus. A 0.2-mg/l chlorine residual inactivated IHN and IPN in 0.5 and 10 minutes, respectively, in soft lake water but had no effect in hard lake water.

The IHN virus survived for less than 2 weeks in phosphate-buffered distilled water at 20° C but survived almost 7 weeks in the two lake waters. IPN virus survived well in all three water types, suffering only a slight reduction after an 8-week holding period.

In summary, the IHN virus is more easily destroyed by both ozone and chlorine than is the IPN virus. If the water is left untreated, IPN titers remain high for at least 2 months but IHN dies out completely, even in hard water.

Standard Methods and Interpretation for Fish Health. — A manual of standard methods has been prepared that includes interpretive tables useful for assessment of the effect of environmental stress on the health of hatchery and native fish populations. The following methods have been included: blood cell counts (erythrocytes, leukocytes, thrombocytes), clotting time, hemoglobin, hematocrit, methemoglobin, plasma, lactic acid, cortisol, glucose, osmolality, and total protein; nitrite and ammonia in water; and glycogen in liver and muscle.

Nitrite Toxicity. — The prevention and treatment of nitrite toxicity is an important consideration in fish production at hatcheries where water is reused. The maximum nitrite exposure that juvenile steelhead trout can tolerate over a rearing season with no methemoglobinemia or decreased resistance to stress, and no adverse effect on ability to convert from fresh to salt water, is not known, and guidelines are needed for water reuse in hatchery operation.

Groups of steelhead trout chronically exposed to nitrite at levels up to 200 ppb for 6 months in soft water at 10° C suffered no significant blood changes, were equally resistant to standardized handling and crowding stress, and converted to salt water normally. Peripheral blood smears and anterior kidney imprints of the fish exhibited no significant changes.

Antidotes to nitrite toxicity were tested with a balanced salt mixture and a 96-hour LC₅₀ as the challenge. Toxicity was greatly reduced as water hardness increased over the range of 10 to 300 ppm. Since pH automatically increases as water hardness increases, the effect of pH alone was tested; it was found that increasing the pH (from 6.0 to 8.0) also gave substantial protection, especially to small fish.

The results of this study suggest that mineral additions might be helpful and also that water chemistry should be taken into account in site selection for future water reuse hatcheries.

It can be expected that biological filters will occasionally fail and that nitrite poisoning of fish will result. Extensive testing showed that as little as 0.01 ppm methylene blue, acting as a pseudo-hemoglobin, gave protection against nitrite poisoning. Methylene blue did not damage the biofilters, and might be a practical treatment for acute intoxication.

Studies on Smoltification. — Research was conducted for the past several years on the role of ATPase in smoltification. Conclusions reached from results of these investigations are summarized as follows: (1) Transformation from parr to smolt is accompanied by an increase in sodium/potassium gill ATPase activity in steelhead trout. (2) External stimuli, such as photoperiod or water temperature, which affect the timing or degree of smoltification, likewise affect the ATPase activity. (3) Gill ATPase activity was elevated in all seaward migrants tested but generally was not elevated in nonmigrants. (4) Treatment or conditions which adversely affect the elevated ATPase activity associated with the smolt stage may also inhibit migratory movement and adaptability to salt water.

Additional studies were initiated to test the effects of adding salt to the diet fed to fall chinook salmon, feeding Terramycin₅₀ at standard levels to the same species of fish, and exposing steelhead trout to light and temperature changes. We also monitored stocks of coho salmon at two Federal and one State fish hatcheries for ATPase/migration activity. Results of these studies follow: (1) The addition of salt increased ATPase activity in fall chinook salmon, as well as survival in salt water. (2)

ATPase activity and saltwater survival of chinook salmon increased with size of fish. (3) Feeding Terramycin had no detrimental effect on ATPase activity or saltwater survival. (4) Under experimental conditions parr-smolt transformation in yearling steelhead trout was accelerated by an advanced photoperiod schedule. (5) Exposure of migrating steelhead trout smolts to water temperatures of 56° to 57° F for 20 days resulted in serious impairment of migratory behavior and in a reduction of gill ATPase activity. (6) Migration tests and ATPase measurements indicate that steelhead trout should be reared to a length of about 16 cm or larger to obtain a high percentage of transformation to smolts. (7) Gill ATPase activity was correlated with parr-smolt transformation of coho salmon at the three hatcheries; time of occurrence varied among the three populations. (8) The warmest water produced the earliest coho salmon smolts, and there was some indication that wide daily temperature fluctuations in cold water hastened transformation.

The results of the ATPase studies have established the importance of ATPase measurements in determining smolt condition.

Sublethal Effects of Sediment Exposure. — Acute and chronic bioassay tests with juvenile coho salmon in a flow-through system were conducted to assess the impact on fish of suspended sediment from a dredging operation. A 24-hour exposure to a 1% suspension of sediment obtained from the dredging project caused mild physiological damage to the gills of juvenile coho salmon. It also caused a mild, but significant, stress response, recovery from which required about 3 weeks.

A chronic 30-day exposure to 70 ppm of the sediment did not cause a stress response. There was more extensive histological damage to the gills, but no interference with physiological function of the chloride cells.

Inheritability of Resistance to Infectious Hematopoietic Necrosis (IHN) Disease. — Diseases can be controlled by prevention, treatment, or selection of individuals with natural disease resistance. Since an inheritable trait to IHN resistance may exist in natural populations of fish, it is important that the level of this inheritance be determined. This information would permit an evaluation of the possibility of selective breeding of fish for resistance.

Eggs from 16 mature female sockeye salmon taken from the spawning grounds were fertilized by a single male per female. Subsamples of the resulting fry were challenged with IHN virus

monthly for 4 months. There was a great variation (50-100% mortality and 9-14 days to death) in the susceptibility of families of sockeye salmon to the disease. These differences were constant within each family over the test period. At the end of the 4 months the fish were pooled in susceptible and nonsusceptible groups. The pooled groups were then challenged for an additional 6-month period. At the end of this time the results indicated that susceptibility or nonsusceptibility was the same as previously, but time to death increased by about 25% in both groups.

The results indicate that resistance is genetic and inheritable at about a 30% level of inheritance.

Infectious Hematopoietic Necrosis (IHN) Disease Studies in Alaska. — Studies in Alaska indicate a widespread distribution of IHN virus in all sockeye salmon populations. Although the virus was found in all localities where fish were tested, prevalence differed among stocks of fish and between sexes.

Females had a significantly higher carrier rate than males. Carriers did not significantly differ from noncarriers in size, and the association of carriers with age class was equivocal. There were no detectable anti-IHN antibodies in the serum or gonadal fluids of carriers or noncarriers. The virus was not detected in sockeye salmon smolts or indigenous nonsalmonid species from a lake included in the studies.

Disease Control. — Disease can be controlled by preventing it, immunizing the host against the causative agent, treating the diseased animals, manipulating the environment to inhibit the agent, and by other means.

The effect of various environmental conditions on the survival of IHN virus was tested. Dehydration of the virus from water at 4° and 10° C resulted in partial inactivation, but dehydration from Hank's Balanced Salt Solution (HBSS) and homogenized fish tissue resulted in total loss of virus activity within 7 days. Survival was not affected by pH between 6 and 8, but virus activity was significantly reduced at pH 5 and 9. Water hardness from 20 to 250 ppm (as CaCO₃) also did not significantly reduce virus activity, but salinity distinctly affected virus survival. Storage in artificial seawater, filtered ocean water, HBSS, and Earl's Balanced Salt Solution (EBSS) equally reduced virus titers. Deionized water and EBSS and HBSS supplemented with protein showed sparing effects. Survival of IHN virus was inversely proportional to HBSS concentration; survival was best when the virus was frozen in media supplemented with 10%

calf serum. Viral activity decreased with an increase of temperature; survival was best at -70°, -20°, and 4° C and poorest at 10°, 15°, 21°, 28° and 32° C. Freezing and thawing of IHN virus had no effect if

the medium contained 10% protein, but freezing the virus in deionized water resulted in a significant loss of infectivity.

Endangered Species

PATUXENT WILDLIFE RESEARCH CENTER

Captive Whooping Crane Produces Offspring; More Hybrids Produced. — This proved to be a banner year for the whooping crane program at Patuxent. The number of pairs producing eggs doubled from one to two, and in spite of an unseasonable heat wave in April that retarded reproduction in most of the cranes, they laid a total of five eggs, up from three in 1975. A weak chick hatched from the first-laid whooper egg on May 5, 1976, and in spite of nearly continual difficulties, it survived, the first to do so from parents raised in captivity. Thus, a major goal of this program — to successfully produce and rear a crane in captivity — has been realized, though artificial incubation procedures with whoopers are yet to be perfected.

A second goal, to reestablish wild flocks from captive stock, took a step toward realization when two eggs were taken to Grays Lake National Wildlife Refuge where they were placed under a preselected pair of sandhill crane foster-parents. Although the two eggs were taken by predators at Grays Lake, the program appears feasible, and plans are well advanced for a continued effort in 1977.

Looming over the efforts to reintroduce whooping cranes at Grays Lake is the ever-present possibility of imprinting: will whoopers raised by sandhills recognize and mate with other whoopers or will they select mates from among the large flocks of young sandhills? If the latter occurs, it is important to know whether hybrids could be produced, what they might look like, and whether they would be fertile. To answer these and other questions, a captive female greater sandhill crane was artificially supplied with semen from a productive whooper. Three eggs laid by this female hatched, and the chicks are being carefully studied.

They show characteristics intermediate between the two parental types and would be very easy to identify in the wild. The young chicks resemble both parents in body conformation, but the characteristic brown plumage of the whooper chick predominates and the legs are black. By fall, white plumage replaces much of the brown in other parts of the body, but a light gray is obvious along the back and near the base of the tail. By the next summer, most of the bird is light gray to white, the legs are dark, and parts of the crown are red. The black cheek patch, characteristic of the whooper, is absent in the nearly white bird. The reciprocal cross using sandhill semen instead of whooper semen may result in a phenotype different from that described.

Patuxent began this investigative period with seven pairs, four unmated birds hatched in 1974, and two extra females. Meanwhile, male whoopers in San Antonio Zoo, and in Audubon Park Zoo, New Orleans, awaited mates. Through cooperative loan agreements, the two females were provided as mates for two of these males: one female was sent to join the famous "Crip" in San Antonio, and another, "Tex," was sent to the International Crane Foundation, where a week later a male from New Orleans arrived to join her. The birds at the Patuxent Center in 1974 formed two loose pairs and will be placed in breeding pens constructed for them this year. Thus, the number of captive whooping crane pairs increased from 7 to 11 in the past year, and the total captive population is only slightly smaller than the entire number of breeding birds in the wild 9 years ago when this program began.

Black-footed Ferret Not Seen in Field for 2 Years. — Black-footed ferrets were not observed on study areas in western South Dakota for the second consecutive year, although surveys were more intensive. The lack of ferret observations is difficult



Female whooping crane incubating at the Patuxent Wildlife Research Center. *Photo by C. B. Kepler.*

to explain, and the failure to find them in formerly occupied areas is cause for concern. The number and size of prairie dog towns have increased substantially in recent years, and more time must be expended on each area to confirm the presence or absence of ferrets. Also, landowners who readily reported ferret sightings in the past are now reluctant to do so. They fear that the reported presence of ferrets on their lands will jeopardize Government-assisted programs for controlling prairie dogs. Meanwhile, prairie dog control is being practiced extensively on privately owned lands and on Indian reservations. Several prairie dog towns in Mellette County, South Dakota, previously occupied by ferrets, have been treated by landowners or tenants.

First Breeding of Black-footed Ferrets in Captivity. — Procedures developed for polecats by Soviet scientists were used in attempts to breed black-footed ferrets at the Patuxent Center. Breeding attempts were initiated when the two females were in peak estrus. After a 42-day gestation period, three neonates were observed in one female's pen. However, they were either killed by the female or died as a result of maternal neglect. Only minimal precopulatory behavior occurred with the other female, breeding was not observed, and no young were produced. Efforts to breed this female were terminated after 11 days, when she was no longer in breeding condition. European polecat females will be used as surrogate mothers during the 1977 breeding season if any litters of black-footed ferrets are produced.



Hybrid whooping crane x greater sandhill crane chicks approximately 5 months of age, produced by artificial insemination of a greater sandhill crane female with semen from a male whooping crane. *Photo by G. F. Gee.*



Black-footed ferret in prairie dog town, Mellette County, South Dakota. *Photo by C. N. Hillman.*

Timber Wolves Increase in Northwestern Minnesota. — Legally protected in 1974, for the first time the wolf population of northwestern Minnesota has responded dramatically. In a 1,000-square-mile study area in that region, wolf numbers increased from an estimated one per 30 square miles

in 1974-75 to one per 17 in 1975-76. Although poaching continues, the kill of wolves by humans has declined considerably. As a result, the survival of pups, dispersal of maturing animals, and colonization of new areas by dispersers have all greatly increased.

Displaced Depredating Wolves Tend to Seek Agricultural Areas. — Wolves preying on livestock in north-central and northwestern Minnesota were livetrapped, translocated to wilderness areas of northeastern Minnesota, radio-collared, and released. Generally, they headed west to south from the release point, and many frequented farming areas. At least two wolves settled near new farms and continued preying on livestock. One of these was retrapped and removed to another location. The other was not recaptured despite intensive efforts.

Eastern Pine Marten Proposed for Endangered Species List. — Observations and accidental captures of martens in traps set for other species have increased in recent years. From 1970 through 1976, 41 martens were caught in Minnesota, and 9 were sighted. This apparent increase in marten abundance is probably a natural extension of the growing population of martens in neighboring Ontario, which began to expand in the 1960's. It is aided by a maturing forest in Minnesota that is beginning to revert to conifers. The greater numbers of martens have drawn the attention of the public and of conservation groups, which have now proposed that the subspecies be placed on the endangered species list.

California Condors Continue to Decline. — The numbers of California condors have continued to decline as a result of their low annual production, averaging less than two young per year. Biologists conclude that the total population has fallen to less than 50 birds. In 1976 there was confirmed production of only one young.

Supplemental feed (animal carcasses) has been provided for California condors almost continuously since November 1974. Condors, in low numbers, fed on many of the animal carcasses placed for them, but with no obvious changes in nesting or other use of the Sespe Condor Sanctuary. Cause of death of an immature California condor found in November 1974 was undetermined. One of the wild condors was brought into captivity after having been found shot in the wing, but it died after surgical removal of the injured limb.

Efforts to Reestablish Masked Bobwhites Take New Directions. — During each of the past 2 years over 2,000 masked bobwhite quail chicks or eggs have been shipped to the Arizona Field Station at

Tucson in attempts to reestablish this subspecies in southern Arizona. Seven different techniques for reintroducing the endangered masked bobwhite were tested in 1975 with one common goal — to produce birds capable of surviving in the wild. The two most promising methods were used in 1976 to release over 850 birds in the wild.

A "call-box" conditioning method has been devised in which 6-week-old birds from captive stock are introduced to unprocessed seed mixtures to simulate wild quail foods and are then placed in covey-sized groups (10-15 birds) in a call-box. (The call-box is divided to allow the birds released from one side to return to the box through funnels on the other side.) After being kept in the call-box for 2 days, some of the birds are released, allowed to wander at will, then "called" into the other side by the covey calls of the retained birds. After the birds have been released and recalled to the box several times, they are then harassed by dogs and persons on foot. When behavior of the birds resembles that of wild birds, they are transported to release locations and set free. Some 130 birds were released by this method, and results are encouraging.

In a second method, foster-parents were provided. Trials were made using sterilized male Texas bobwhites, male and female Gambel's quail, a male scaled quail, and call-box trained masked bobwhite males, females, and pairs as foster-parents. Over 300 chicks were released with quail foster-parents. The more promising results were produced by assigning 10 chicks (4-10 days old) to the male Texas bobwhites, Gambel's quail, and scaled quail. Because of potential interspecific imprinting and other possible behavioral problems, adoptions were restricted to Texas bobwhite quail in 1976.



A male Texas bobwhite, upper left, leaves the release box with a brood of adopted masked bobwhite chicks produced at the Patuxent Wildlife Research Center. Photo by D. H. Ellis.



Female Florida everglade kite returning with apple snail to nest containing two kite chicks, headwaters of the St. Johns River, Florida. Photo by P. W. Sykes, Jr.

In another release method, masked bobwhite eggs are placed in the nests of other native quail. Only a small trial of this method was possible; 15 eggs were placed in one scaled quail nest. Ten eggs hatched, and masked bobwhites were seen in a scaled quail covey in the fall. This method is potentially valuable, but more wild nests must be found before a suitable trial can be made. Chicks that were newly hatched or no more than a few days old were placed with broody bantam hens, who raised the young in a semidomestic state at the Arizona Field Station headquarters. This method proved unsuccessful in trials with 61 chicks.

Survival success of the released birds cannot be properly evaluated until early in 1977; however, as of September 1976, a few coveys appear to be established and thriving in the wild. Some of them have been fending for themselves for over 2 months. Meanwhile, observations of masked bobwhite numbers in Sonora, Mexico, indicate that the condition of the only remaining wild populations is worsening. Establishment of a refuge or management area now appears necessary to prevent complete extirpation of masked bobwhites south of the border.



Young Florida everglade kites in artificial nest structure in cattails, Lake Okeechobee, Florida. Kite nests located insecurely in vegetation threatened by high water or wind have been successfully moved into these artificial structures and the young have fledged. Photo by P. W. Sykes, Jr.



Florida everglade kites resting during mid-day on the Loxahatchee National Wildlife Refuge, Florida. Photo by P. W. Sykes, Jr.

Endangered Clapper Rail Continues to Decline.

— The population estimate of the light-footed clapper rail in California has been revised downward as a result of continuing surveys. Probably not over 300 light-footed clapper rails still inhabit 14 remnant salt marshes along the southern California coast.

The Status of the Everglade Kite in Florida. — Annual censusing each fall (1969-75) has averaged 92 Everglade kites. The population has remained relatively stable at this low level with fluctuations from 65 to 120 during the period. A total of 110 birds were seen on the 1975 census. Sixty-four nestling kites have been color-banded since 1968. The oldest known banded kite surviving in the wild is now 8 years old. How long they may be expected to live has not been determined, although closely related South American snail kites in captivity at the Patuxent Center are 11 years old.

Since 1972, most nesting activity has been at Lake Okeechobee. In 1976, there were 23 nests on the lake, 10+ in Conservation Area 3A (CA3A), and 1 at Loxahatchee National Wildlife Refuge. This is only the second time since 1968 that kites have been found nesting in CA3A. For the last 9 years, 42% of the nesting attempts have been successful. These nests produced an average of two young each. Nesting failure can be traced to at least 10 different causes, predation being the major problem.

Out of approximately 2.5 million acres of freshwater marsh, about 15-16% is known to have been used by kites since 1967; not more than 10% is estimated to be used in any 1 year. In a drought year this percentage is still further reduced. Lake Okeechobee and southern and eastern CA3A are the most heavily used areas at present. Under existing conditions, all habitat in Florida is considered marginal for kites on a long-term basis. This precarious situation can be corrected through land acquisition, habitat development, and management.

Hawaiian Forest Birds Inventoried. — Patuxent biologists worked closely with the Pacific Endangered Species Coordinator and cooperators in planning and carrying out the first comprehensive inventory of Hawaiian forest birds in the Ka'u forest on the lower southeast flanks of Mauna Loa, island of Hawaii. Forest bird census stations established on transects in the Ka'u forest were visited by survey teams following a rigorous schedule and equipped with tents and backpacks. The survey was completed in 4 months, May through August 1976, and the findings are being analyzed and prepared for publication. The techniques used are expected to be generally applicable for future surveys of forest birds elsewhere in the Hawaiian Islands, although some modification of design may be necessary for special situations. A by-product of these surveys will be a list of management recommendations that will include proposals for land acquisition.

Substantial Gain Reported for Wild Puerto Rican Parrots. — The wild population of Puerto Rican parrots (*Amazona vittata*) experienced two unusually good breeding seasons in 1975 and 1976. Six young fledged from five active nests in 1975 and eight young fledged from four active nests in 1976. The production of young now seems strong enough to balance mortality, and the wild population has finally halted its decline, at least temporarily. As of June 1976 there were 22 parrots in the wild, the first time the population has exceeded 20 individuals since 1969. However, the age structure of the population is now skewed heavily toward immatures — the number of breeding pairs has not increased.

Part of the increase in reproduction can be attributed to the acceptance by parrot pairs of three artificially constructed nest sites. It appears that all mature pairs laid eggs in both 1975 and 1976 and that the problem of too few nest sites is now solved.

Since 1973, nest success has averaged better than 70%, a distinct improvement from the 20% characteristic of these parrots for years prior to intensive management. Improvement in nest success is due largely to management efforts to improve nest sites (particularly keeping them dry through the breeding season) and to reduce the impact of predation by pearly-eyed thrashers (*Margarops fuscatus*). Thrasher predation on eggs and young of parrots has been reduced by three basic techniques: (1) Parrot nests were sedulously guarded during the critical early stages of the breeding cycle. Watchers in blinds shot or frightened away intruding thrashers. (2) Parrot eggs were artificially incubated at the field station. The wild pairs were kept active on plaster of paris eggs during the incubation period. Nestling parrots were returned to the nests in the wild. In 1975, the value of this technique was clearly demonstrated at one nest in which the plaster eggs were extensively damaged by thrashers. (3) Parrot nests were modified to make them unattractive to thrashers, and alternative sites for thrasher nests were provided near the parrot nests. Several parrot nests were deepened beyond the depth preferences of thrashers, and thrasher pairs accepting nearby shallow nest boxes effectively defended the parrot nests from other thrasher pairs prospecting for nest sites. With the apparent success of this technique in 1976, all parrot nests are now being deepened to appropriate depths and thrasher boxes are being placed nearby in hopes that this method may prove to be the most efficient and effective solution to the thrasher problem.



Young Puerto Rican parrot close to fledging from a human-excavated nest site in Luquillo Forest. This 6-foot-deep hole was the first nest in recent years free from pressure of pearly-eyed thrashers. *Photo by H. Snyder.*



Two-week-old Puerto Rican parrot nestling with a neck wound received from a pearly-eyed thrasher. This chick recovered and eventually fledged successfully. *Photo by N. Snyder.*

Since 1973 at least two and possibly as many as six successful parrot nests would have been lost to thrasher predation if the precautions described above had not been employed. Thrashers have destroyed only one parrot egg during these years, as far as we know.

As of 1976 the captive Puerto Rican parrot population stands at 11 birds. No reproduction has yet occurred in captivity, although several infertile eggs have been laid. All captives taken in 1975 were parrots that would not have survived in the wild because of botfly parasitism or nest desertion. No new captives were taken in 1976.

Puerto Rican Boa May Not Be Endangered. — Records accumulated in the last few years suggest that the Puerto Rican boa is far more common than was earlier supposed. The species is present in a wide variety of second-growth habitats in all major regions of the island. Because of its secretive habits the species is not easy to observe, and most records are of boas crossing or killed on highways or discovered by laborers clearing brush. The widespread distribution of recent sightings and the fact that almost all rural people interviewed across

the island have had recent personal experience with the species can only mean that it is reasonably common. It probably should be withdrawn from the list of endangered species.

Peregrine Falcon Search in Arizona Reveals Significant Numbers of Adult Birds. — In 1976 a comprehensive search was made to determine the occupancy of over 40 historic summering or breeding sites of peregrine falcons in Arizona. Most sites are now vacant, but 12 sites had one or more adult birds in 1975 or 1976. A few immature birds have also been observed. Most of the active sites are so remote that the nesting cliffs have not been identified. Arizona appears to have a large share of the remaining scant breeding population of the American peregrine falcon and could contribute significantly to restoration efforts.

PYRAMID LAKE PROJECT

Effect of Dissolved Solids on Cutthroat Trout and Cui-ui. — Pyramid Lake, Nevada, is the terminus of the Truckee River, the only permanent stream entering the Pyramid Lake basin. The water level of the lake had become relatively stable, within recent geological time, balancing between inflow and losses from evaporation and seepage. Upstream development within the past century has diverted large amounts of water from the river with a concomitant decline in the water level of the lake and a consequent rapid increase in the concentration of total dissolved solids. The purpose of our project

is to determine the effect of increasing these solids in the lake, on the threatened and endangered species — the cutthroat trout and the cui-ui.

Project personnel are procuring and installing the diverse types of equipment necessary to provide 20 closed-system units which will contain paired replicates of the two test species reared in five concentrations of water, i.e., fresh and Pyramid Lake water x 0.5, 1.0, 1.5, and 2.5. Concentration above Pyramid Lake x 1.0 will be obtained by heat-assisted, high-vacuum evaporation. The study will

be continued until the test fish are sexually mature.

Inadequate design of the lake water supply system has delayed the beginning of the experimental study. Correction of this deficiency, and completion of the evaporator-steam boiler unit installation will permit the study to begin. Yearling cutthroat trout are currently being maintained in the experimental units for the purpose of conditioning filter beds and to simulate study conditions, including analytical chemistry procedures and experimental culture techniques.

Great Lakes Fisheries

FISH CONTROL LABORATORY

Registration of Lampricides for Fish. — The registration of chemicals used in fisheries continued to receive major emphasis during the year. Studies at the Fish Control Laboratories at La Crosse, Wisconsin, and Warm Springs, Georgia, were directed toward fulfilling requirements of the Environmental Protection Agency and the Food and Drug Administration. Many of the compounds now in use have never been registered or face reregistration deadlines in upcoming years. Data requirements to support applications for registration have risen significantly in recent years. All applications must now include test results to show that the chemicals are effective, that they have no lasting adverse effect on other biota, that they leave no harmful residues or degradation products in treated animals or the environment, that they are not carcinogenic, teratogenic, or oncogenic, and that they constitute no human health hazard.

Significant progress was made during the year. A research protocol on the lampricide, TFM, was completed and an application for amended registration was submitted to the EPA. Data included with the submission demonstrate that the use of TFM as prescribed on the proposed new label is safe and efficacious for control of the sea lamprey in the Great Lakes.

Work on another lampricide, Bayer 73, is nearing its final stages. Studies conducted in Boardman Lake (Michigan) indicated that although treatment

of the Boardman River delta for larval lampreys resulted in a temporary depression of the numbers of invertebrates found in the stream bottom, the effect was temporary. Both the number and species diversity of organisms found after treatment indicate no lasting adverse effects.

Laboratory tests of Bayer 73 revealed that selected species of snails differed widely in susceptibility to Bayer 73. The 96-hour LC₅₀'s were 1.16 mg/l for *Helisoma* sp. and 0.0625 mg/l for *Lymnaea* sp.

The freshwater prawn, *Palaemonetes kadiakensis*, was much more resistant; the 96-hour LC₅₀ was 9.0 mg/l. Concentrations in excess of 10.0 mg/l decreased the percentage of hatch in eggs of the leopard frog.

Brook trout injected intraperitoneally with 0.1 mg of Bayer 73 survived for 48 hours with no overt signs of toxicity. Analysis of blood and bile revealed a drop in calcium and a rise in magnesium levels in the bile-to-plasma ratios of treated fish.

Development of methods for the analysis of Bayer 73 in the environment met with partial success. Two procedures were found for the determination of Bayer 73 levels in water. Both involve hydrolysis of Bayer 73 and color development of the aniline portion. There is no detectable interference from TFM or from phytoplankton. Time to complete an analysis is less than 1 hour. For the first time, field crews of the sea lamprey control program have a tool to help them accurately determine levels of the chemical in



Bile collected from a trout exposed to use pattern levels of Bayer 73 will be analyzed for metabolites and residues. *Photo by L. L. Marking.*

treated streams.

Efforts to develop procedures for the determination of Bayer 73 residues in fish tissue were stymied by findings that residues of the chemical could not be separated from lipid materials in the samples. Although acetone extraction of fish muscle provided 98% recovery of ^{14}C -labeled Bayer 73 in laboratory tests, the extracts could not be analyzed with existing methodology because of interference from the naturally occurring fats. Until this problem is resolved, progress on residue studies is not possible.

In laboratory studies conducted to improve field procedures for using Bayer 73, we found that little Bayer 73 goes into solution at pH's below 7.0. The amount that goes into solution is greatly reduced at low temperatures; about twice as much dissolves (per unit of time) at 12°C as at 7°C . Awareness of these antagonistic factors has made it possible to

more successfully treat lamprey-containing waters with Bayer 73.

Other findings included observations that the "fines" present in currently used formulations may be too small to overcome surface tension of the water. Data on efficacy indicate that a 1% formulation might increase efficacy, but that it would involve significantly increased costs in material, shipping, labor, and time.

GREAT LAKES FISHERY LABORATORY

Restoration of Lake Trout in Lake Superior. — Populations of lake trout, an important commercial and sport species in Lake Superior, were greatly reduced in the 1950's due to intense exploitation and predation by sea lampreys. Partial control of the sea lamprey, protective fishery restrictions, and

intense stocking resulted in a great increase in trout abundance in much of the lake by 1971. But populations are now the object of a large and expanding sport fishery in Michigan and Wisconsin, still threatened by continued sea lamprey predation throughout the lake, affected by great variation in annual plants of hatchery-reared fish, and subjected to increased commercial fishing by Indians in Wisconsin and Whitefish Bay, Michigan.

Various population indices derived from technical data obtained annually by "contract" fishing, research vessel surveys, and fishery censuses indicate that lake trout stocks continued to improve in Minnesota and most of Michigan in 1975. In Michigan, for example, fish 838-937 mm (33.5-37.5 inches) long tripled in abundance, and for the first time in 17 years of assessment fishing, a lake trout longer than 1,000 mm (40 inches) was caught. However, serious problems appear to have developed among stocks in Wisconsin and in Whitefish Bay, Michigan. In Wisconsin, abundance had stabilized in 1974 after three consecutive years of decline, only to decline again by more than 20% in 1975. Abundance in Wisconsin waters is estimated to be about half of what it was during the peak years of 1970-71. In Whitefish Bay, abundance also fell drastically — more than 70% from the peak in 1973.

The abundance of spawners declined alarmingly since 1974 in the Apostle Islands region of Wisconsin — 48% on Gull Island Shoal and over 80% at Michigan Island. The Gull Island Shoal-Michigan Island population is composed mainly (70-75%) of native lake trout and is the only population in southern Lake Superior that appeared to be self-sustaining. Apparently the sharp decline was caused by excessive exploitation in 1975. The Wisconsin Department of Natural Resources (WDNR) made mortality and population estimates of this stock by tag-and-recapture methods in 1974 and 1975. The commercial catch is closely monitored and a creel census provides data on the sport catch. The known catch represents a 46% fishing mortality on lake trout longer than 635 mm (25 inches). The components of this mortality consist of sport fishing, 13%; Indian commercial fishing, 29%; other commercial fishing, 3%; and the WDNR's assessment fishing and egg-taking operations, 2%.

Although these specific declines are alarming, the overall lake trout picture exhibits some encouraging trends. Among cohorts of lake trout planted at various times over the last 15 years further east in Keweenaw Bay and in the Marquette-Munising

area, the total annual mortality between ages IX and XIII has declined sharply. Annual mortality of lake trout between ages VI and IX was on the order of 0.65 to 0.80 during the late 1960's, when mortality beyond age IX averaged almost 100% and few females reached maturity. In the past 6 to 8 years, total mortality has fallen to about half the 1966-68 level, and relatively strong spawning populations have developed at several locations. The estimated sport, commercial, and incidental catch of lake trout in Michigan waters now approximates half the historic commercial catch before the great decline of the 1950's.

Furthermore, the incidence of fresh sea lamprey wounds in the spring of 1975 remained near the low 1974 levels on all sizes of lake trout. Since 1964, the wounding rate for 17- to 20-inch fish has changed little. However, wounding on 21- to 24-inch fish declined about 35%, that on 25- to 28-inch fish about 47%, and that on 29-inch and larger fish, about 55% over the same period. These trends probably reflect substantial changes in the predator-prey ratios that have been altered more by increases in abundance of the larger trout than by decreases in abundance of sea lampreys.

Decline of Lake Superior Herring Stocks. — Landings of lake herring in U.S. waters of Lake Superior declined from a peak of 17.8 million pounds in 1941 to only 314,000 pounds in 1975. Landings in Canadian waters still exceeded the 1941 catch there of 1.4 million pounds. Although overfishing is suspected as the major cause of decline of herring stocks, predation on, and competition with, the larvae by rainbow smelt have also been widely proposed as possible causative factors.

During fiscal year 1976, examination of all commercial fishing records from Wisconsin waters of Lake Superior from 1940 to 1961 was completed, along with the extraction of all lake herring catch and effort statistics. Fishing localities were identified by statistical grid.

Preliminary analyses point toward the sequential "fishing-up" of individual (local) populations as having been primarily responsible for the historic declines in lake herring. For example, during the decade 1950-59, the total harvest from Wisconsin waters averaged 4,290,000 pounds per year, of which 98% was taken in bottom-set gill nets during the fall spawning season. About 60% of the fish produced were taken in two relatively small Wisconsin bays: Siskiwit Bay near Cornucopia (880,000 pounds) and Big Bay on Madeline Island (1,690,000 pounds). During this decade, total effort

in these two bays nearly doubled while the catch declined — from about 3,430,000 pounds in 1950-52 to about 980,000 pounds in 1957-59. The next phase of our study will deal with biomass estimates and yield projections as guides to future management of this species.

The possibilities of significant smelt predation on, or competition with, larval lake herring were studied during 1974-75 in a cooperative program between the Service's Ashland Biological Station and the Ontario Ministry of Natural Resources at Thunder Bay. Most sampling was done during May and July in Black Bay, Ontario, and in the lake proper among the Apostle Islands, Wisconsin. The herring in Black Bay are still abundant and annually yield about 1.5 million pounds, whereas in the Apostle Islands they are sparse and declining in number. Smelt are about equally abundant in the two areas.

In examining the question of competition, we observed that lake herring began feeding shortly after hatching — all or nearly all before the yolk sac was fully absorbed — and that their food was similar in the two sampling areas: mainly copepod nauplii at first, then larger copepods as the herring grew. Smelt eggs hatched inshore, and much later in the year than herring eggs; thus larvae of the two species did not cohabit the area studied and could not have competed for food. Although juvenile (age I) and adult (age II and older) smelt occupy the same areas as herring larvae, they eat different invertebrate species (or life stages thereof) than do herring larvae and therefore do not compete directly for food. The species composition of the zooplankton showed no evidence that it had been altered through selective feeding by smelt in any way that would be harmful to herring larvae.

To evaluate predation, we examined stomachs from a total of 1,195 Black Bay smelt, of which 685 (57%) contained food. Of the 685 smelt with food, 204 (30%) contained one or more herring larvae. We also examined the stomachs of 1,711 Apostle Islands smelt, of which 1,146 (67%) contained food but no herring larvae. Predation on herring by smelt, as observed in spring 1974, is probably not high enough to be a matter of concern, especially since the herring population of Black Bay appears to be relatively stable. The total number of herring larvae migrating out of the bay is probably sufficient to maintain the fish population in the open lake. We believe that predation in the open lake, as in Wisconsin waters, is low or nonexistent. Our failure to detect any predation in Wisconsin suggests that smelt predation plays no role in the

continuing decline of the herring population in the open waters of southwestern Lake Superior.

Update on Morphology of Lake Superior Coregonines. — The systematics of Lake Superior ciscoes have perplexed field biologists for years. But today, with stocks of some species greatly diminished, there is a critical need for a more reliable field method for distinguishing the forms so they can be adequately protected and the fishery properly regulated. During 1975-76, we clarified the relationships between these ciscoes by using modern analytical techniques such as cluster-analysis, principal-components, and discriminant-functions.

For *Coregonus nigripinnis cyanopterus*, *C. reighardi dymondi*, and *C. zenithicus*, a total of 27 meristic and morphometric characters were measured, including gillraker number, fin lengths, fin rays, jaw lengths, snout length, and eye diameter. All study specimens were from collections in the University of Michigan Museum of Zoology made by Walter Koelz for his 1929 monograph, *The Coregonid Fishes of the Great Lakes*.

Principal-components analyses demonstrated that the *C. nigripinnis cyanopterus* were merely large specimens of *C. zenithicus*. Slight differences in body proportions associated with large size were the only discriminating features of *C. nigripinnis cyanopterus*.

In contrast, *C. reighardi dymondi* was recognizably distinct from *C. zenithicus*. The geographic distributions of the two forms overlapped, and principal-components analyses showed that *C. reighardi dymondi* was less similar to *C. zenithicus* populations within the area of overlap than to populations outside it. This character displacement further suggested that these two forms were distinct. *C. reighardi dymondi* was restricted to the large bays and immediately adjacent waters of northwestern Lake Superior, but included Lake Nipigon, Ontario. *C. zenithicus* was found throughout Lake Superior, but we believe that records of its occurrence in Lake Nipigon were due to misidentification.

Condition and Management of Lake Michigan Chubs. — The bloater is the last commonly occurring representative in Lake Michigan of an original group of seven deepwater ciscoes or "chubs," important coregonines that once sustained a sizable commercial fishery and provided a forage base for lake trout. Smallest of the seven species, it has represented more than 99% of the fishable chub stock since the early 1960's. Chubs declined drastically in abundance in the 1960's and early



Gill net sampling of bloater chub stocks in Lake Michigan. This species has seriously declined in abundance since the mid-1960's and a lakewide moratorium on commercial fishing has recently been imposed. *Photo by R. M. Julian.*

1970's — possibly because of competition from alewives and smelt and (more recently) depletion of spawning stocks through exploitation.

Comprehensive surveys by the Fish and Wildlife Service in 1974 revealed that chub abundance was but a small fraction of what it had been in 1960 and 1961 — down to less than 1% in western and northern Lake Michigan. Results of similar surveys in 1975 showed little or no improvement in the depleted chub stock, despite temporary bans on fishing in 1975 as the states sought legislative and judicial means for permanently closing the chub fishery. To slow down declining recruitment and foster possible rebuilding of the resource, the Great

Lakes Fishery Commission's Chub Technical Committee, which is composed of Service and State biologists, recommended such closure in 1974. Preliminary results of special sampling with gill nets and trawls in June 1976 suggested that, although chub populations in southern Lake Michigan are still only a fragment (1 to 5%) of what they were in 1960, the downward trend may have been at least temporarily halted in some areas by improved recruitment from one or two recent year classes.

State efforts during 1975 and 1976 to ban fishing on the severely depressed chub population were challenged repeatedly in the courts by the fishing

industry, and only by late summer of 1976 did it appear they would be successful.

Lake Michigan Alewife Stock in Healthy Condition. — During the Laboratory's resource surveys with experimental trawls in fall 1974, body-weight indices, which reflect the general physical condition of adult alewives, fell to the lowest levels recorded for Lake Michigan since the huge population buildup that preceded the massive die-off in 1967. Because poor physical condition limits the ability of alewives to withstand temperature stresses in winter and early spring, we predicted that a heavier die-off than in recent years might occur in 1975. Moderately heavy concentrations of dead alewives were later seen from research vessels along the east shore of the lake in spring 1975. A commercial fisherman in the Frankfort, Michigan, area also reported in late June that the die-off there was the largest he had seen in several years. By fall 1975, the physical condition of the adults had improved throughout the lake, and we predicted that die-offs in the spring of 1976 would be relatively light. Observations from various Federal and State research vessels during the spring of 1976 substantiated this prediction.

Despite considerable year-to-year variation, alewife samples taken by bottom trawls at permanent index stations throughout the lake, and the temporarily poor physical condition of alewives generally in 1974, the stock itself continues to appear to be stabilized at a substantially high level. The average catch per unit of sampling effort (CPE) for adults at four index stations in southern Lake Michigan (410 fish per 10-minute trawl tow) in fall 1975 was the highest recorded since 1967. This high rate was mainly attributable to record catches off Benton Harbor (555 fish per tow) and Waukegan (861 fish). The combined CPE for young-of-the-year was down somewhat from 1974 but was still the third highest of the 9-year survey period. Lake-wide, adult alewives appeared to be more abundant in 1975 than in 1974, whereas the young were less so — although they were by no means scarce.

Assessment of Lake Michigan Lake Trout. — Lake trout supported the most valuable commercial fishery in Lake Michigan for nearly half a century. In the mid-1940's, however, the species began a decline that led to its extinction there by 1956, chiefly due to mortality imposed by the sea lamprey. Present efforts to rehabilitate the lake trout involve both sea lamprey control and the stocking of hatchery-reared fish, both of which are administered by the Service through the Great Lakes Fishery Commission. Good survival has

permitted lake trout to become abundant again, although they have not yet reproduced naturally in Lake Michigan. Fishery managers must have continuous information on the distribution, abundance, and vital statistics of the lake trout stock to restore it to self-sustainability and maximum productivity, to gauge its performance in response to exploitation, and to project its annual surplus production for allocation among the various users.

Samples of Lake Michigan lake trout for data on abundance and age distribution, and on the incidence of sea lamprey wounds, were collected again in late 1975 off Saugatuck for the fifth consecutive year. The collections included 890 lake trout planted lakewide as yearlings in the springs of 1967-75; 11 stocked off Ludington, Michigan, as fingerlings in the fall of 1967; 57 released off Grand Haven, Michigan, as fingerlings in the falls of 1971-74; and 13 for which the origin could not be determined. Not represented in the catches were fish planted in spring 1965 and 1966, which unquestionably have become very scarce.

As indicated by the number of fish caught per unit of sampling effort, the overall abundance of lake trout off Saugatuck did not appear to be greatly different in 1975 than in several previous years. The average weight of fish in 1975 was 2.9 kg, as compared with 2.4 kg in 1974. Sea lamprey wounding rates in 1975 climbed moderately, but not alarmingly, from the extremely low levels of 1974. The 1975 rates were 3.4, 1.5, and 3.6% for fish in the 533- to 634-mm, 635- to 735-mm, and 736- to 837-mm length classes, respectively. Rates in 1974 were less than 1% in all length categories.

Laboratory staff members joined State personnel in the first meeting of another technical working group organized by the Great Lakes Fishery Commission, this one addressing the problem of interagency assessment and management of fisheries for lake trout in Lake Michigan. The group's long-range goal is to develop the strategy for a unified, interagency program of lake trout assessment that will provide a scientific data base for possible management (on a lakewide basis) of the stock and the fishery it supports. Now under way is a multiagency effort to assemble and begin analysis of all available data on the fisheries, biology, and dynamics of the lake's past and present lake trout resource.

Status of Lake Michigan Yellow Perch. — Yellow perch populations throughout Lake Michigan have changed greatly in recent years, as evidenced by assessment surveys as well as by

commercial and sport catches. In the early 1960's, high commercial production, together with high catch per unit of effort, was followed by an abrupt decline. The sequence occurred somewhat earlier in northern than in southern reaches of the species' primary range in Lake Michigan. A nearshore sport fishery, conducted mostly from breakwalls in the lake proper and from boats in Green Bay, collapsed a few years earlier than the commercial fishery. Fortunately, this decline has apparently reversed, and catches by the commercial fishery (in waters where it is still allowed to operate) and the sport fishery have partly recovered in the 1970's. Commercial fishing for perch is now banned in Michigan but allowed in other states. However, the Michigan Department of Natural Resources is considering the long-range possibility of a limited-entry commercial fishery for perch with entrapment gear, consistent with protection and sustained productivity of the stocks.

As revealed by our annual systematic sampling in 1975 around the perimeter of Lake Michigan, yellow perch continue to be most abundant in the southeastern sector of the lake. Their persistent scarcity along the western shore suggests that a recovery of perch stock there, similar to that which occurred along the eastern shore several years ago, will not take place in the foreseeable future.

Forage-fish Stocks in Lake Huron. — Success of the intensive program by United States and Canadian fishery managers to reestablish self-sustaining lake trout populations and introduce Pacific and Atlantic salmon, splake, and other salmonids in Lake Huron relies heavily on the adequacy of the forage base to support large populations of predator species. Information on the size and composition of the forage base, primarily alewives and rainbow smelt, must be accurate and timely if it is to be used effectively by fishery managers. Survey and biostatistical data must be developed for use in computation of standing stock, turnover rates, and surplus production of the forage fish.

Systematic sampling with mid-water and bottom trawls at permanent index stations off Hammond Bay, Alpena, Harbor Beach, and AuSable Point during 1975 provided the third year of base-line data on the distribution, abundance, and biology of alewives and smelt. Alewife abundance increased during 1975 for the second consecutive year; catch of adult fish per unit of effort was 50% greater than in 1974. Smelt abundance was essentially the same in 1975 as in 1974 but appeared to have increased somewhat in the spring of 1976.

Catches of young-of-the-year alewives during fall surveys are closely correlated with catches of yearlings the following spring. This fact and collaborative age and growth data suggest that the fall catch of young-of-the-year represents an early and reliable indicator of relative year-class strength. Our predicted catch of alewives per unit of effort in the spring of 1976 was within 0.5% of the actual catch.

Estimates of the standing stocks of alewives and smelt were derived from average densities of each species by combining mid-water and bottom components of the populations and expanding such densities by depth-contour intervals to encompass all U.S. waters of Lake Huron. The standing stocks in the fall of 1975 were estimated at 31,000 metric tons of alewives and 18,500 metric tons of smelt. Continued refinements of our estimates and their integration with analyses of age and growth will improve our ability to accurately project standing stocks of forage fishes.

Status and Management of Lake Erie Walleyes and Yellow Perch. — Surveys during 1975 indicated that the walleye population in Lake Erie's western basin is probably the largest it has been since the mid-1950's. Moreover, the age structure of the population appears to be stabilizing, with many year classes and older age groups well represented. This resurgence may be attributed to restraints on commercial fishing since 1970 and to the production of relatively strong year classes in 1970, 1972, and 1974.

In contrast, the population of walleyes in eastern Lake Erie appears to have weakened. Samples of commercially caught walleyes showed the presence of only one strong year class (1971), which made up the bulk of both spring and fall landings. As this year class disappears, without sufficient replacement, the take of walleyes from the eastern basin is expected to decline significantly in 1976.

Yellow perch populations continued to deteriorate in 1975, especially in the western basin. The lake-wide commercial catch of 9.9 million pounds was the lowest recorded since 1966 and, before that, 1955. In addition, the 1972-74 year classes are comparatively weak and are not expected to make significant contributions. The 1975 year class, as indicated by data from the Ohio Department of Natural Resources, was somewhat stronger and may become the mainstay of commercial production during 1978-79.

The Scientific Protocol Committee on Interagency Management of the Walleye Resource of Western Lake Erie, sponsored by the Great Lakes Fishery

Commission, presented its First Technical Report to the Commission's Lake Erie Committee in mid-June 1976. In brief, the report described the Protocol Committee's procedure in developing a technical basis for managing the walleye fishery by means of catch quotas for each regulatory agency. Among other considerations, the Protocol Committee (1) determined that the moratorium on commercial fishing imposed in 1969, together with highly favorable spawning conditions in several intervening years, has permitted the stock to recover rapidly; (2) projected the 1976 standing stock of catchable-size walleyes at almost 9 million fish; (3) forecast the stock's expected surplus production at slightly over 900,000 fish weighing about 1.6 million pounds; and (4) recommended catch quotas of 80,500 walleyes for Michigan, 335,000 for Ontario, and 479,500 for Ohio. Follow-up recommendations for 1977 are in preparation.

A technical committee to develop the scientific rationale for adjusting the minimum commercial size limit for yellow perch in western Lake Erie was appointed at the Lake Erie Committee meeting of the Great Lakes Fishery Commission in March 1975. This committee, composed of representatives from Ohio, Ontario, and the U.S. Fish and Wildlife Service, submitted its report to the Lake Erie Committee in January 1976. The report concluded that under heavy exploitation, with the present minimum length limit of 8 inches, and in the absence of any strong year classes produced since 1965, the yellow perch resource of western Lake Erie has severely deteriorated in recent years. The Committee recommended an increase in the minimum length limit to 8½ or 8¾ inches and urged a firm commitment from all agencies to strictly enforce any new limit imposed.

Effects of Egg Predation and Environmental Factors on Production of Walleyes in Western Lake Erie. — In a previous study, marked annual differences in year-class success (1960-70) could not be correlated with differences in brood stock size. However, the rate and regularity of water warming during the spring spawning and incubation periods were shown to be strongly correlated with the density of egg deposition and resulting year-class strength. Although slower-than-average rates of warming were not themselves detrimental, low temperatures extended the length of the incubation period, which in turn increased egg exposure to such negative influences as dislodgment from spawning reefs by strong currents, siltation, and low dissolved oxygen. It is hoped that the recovery of the walleye brood stock during the past several

years, and the expected increased egg deposition in a greater number of spawning locations during years with adverse environmental conditions, will help insure at least a fair hatch and year class. Evidence suggests that this happened in 1975.

In another study published during the year, examination of stomachs from 21 species of fish captured over a walleye spawning reef in western Lake Erie disclosed that spent yellow perch were the most consistent predators on walleye eggs. Yet, never in 3 years of observation were spent yellow perch abundant enough on the walleye reefs to impose serious mortality on walleye eggs. Only under the very uncommon condition of an extended time overlap between walleye egg hatching and perch spawning, resulting in the presence of large numbers of actively feeding spent perch, could egg predation reduce walleye reproductive success.

Development of a Chemosterilant for Sea Lamprey. — The sea lamprey is now being controlled with chemicals at a level corresponding to about 10-20% of its peak abundance in the late 1950's. The chemical control program that selectively destroys the stream-dwelling larvae is very costly, however, and further reduction in lamprey abundance by this means would be prohibitively expensive. Consequently, the Great Lake Fishery Commission has established the long-range goal of developing an integrated control program that will include the continued application of selective larvicides where appropriate, as well as any other methods that may prove effective in attaining the desired level of control. One of the new sea lamprey control methods now being developed and evaluated by the Great Lakes Fishery Laboratory, under contract with the Great Lakes Fishery Commission, involves the release of artificially sterilized, sexually mature lampreys into streams containing spawning populations of lampreys. In principle, these sterile individuals will compete successfully with fertile ones for mates and thereby reduce the reproductive success of the spawning population. Search for a chemosterilant that would permit testing of the sterile-lamprey release technique was initiated at the Laboratory's Hammond Bay Biological Station in 1971. Tests at the Station showed that *P,P*-Bis (1-aziridinyl)-*N*-methylphosphinothioic amide ("PMPA") dissolved in saline and injected intraperitoneally at a dosage of 100 mg/kg sterilizes spawning run sea lampreys. Field tests conducted in 1974 on an experimental population of spawning adults established in an isolated portion of the Big Garlic

River, Marquette County, Michigan, confirmed that treatment of male sea lampreys with PMPA sterilized them; these field studies also showed that PMPA treatment had no apparent effect on the nest-building activity, spawning behavior, or mating competitiveness of the sterilized lampreys.

A second field study was conducted in the Big Garlic River in 1976 to provide a quantitative demonstration of the effectiveness of the technique. On June 5, 1976, a total of 270 PMPA-sterilized male sea lampreys, together with 30 normal males and 70 females, were released in the study area. Spawning began on June 20 and continued through July 6. The study area was surveyed daily, and a total of 213 lamprey nests were found. A case history was kept of the lamprey activity at each nest through July 6. On July 6-8, all 213 nests were sampled to determine if they contained eggs or embryos and to ascertain the stage of development of those present. Seventy-four nests containing live eggs or embryos were found; each of these nests was then completely excavated and the contents were washed into a fine-mesh plankton net and preserved for analysis. Preliminary analysis of these preserved samples indicates that viable offspring were produced only in nests where normal males spawned with normal females. In nests where sterile males spawned with normal females, embryos developed through the early stages and then died. The available information suggests that a quantitative demonstration of the effectiveness of the sterile-male lamprey release technique will be possible when analysis of the preserved samples is completed.

Benthos Populations as Indicators of Habitat Quality. — The St. Marys River, connecting Lakes Superior and Huron, is a heavily traveled shipping route and is also the recipient of municipal and industrial wastes of two cities. River populations of warm- and cold-water fishes support an important sport fishery. Many of these fish feed extensively on the benthic invertebrate fauna, the more important of which are mayfly nymphs and caddis fly larvae. Urban and industrial growth, as well as an extended shipping season, represent possible threats to the quality and abundance of the river's macrobenthic invertebrate fauna.

Limited sampling by the Great Lakes Fishery Laboratory in 1971-73 indicated that populations of mayfly nymphs and caddis fly larvae were abundant in many parts of the St. Marys river, except those polluted by industrial wastes; it failed, however, to provide a comprehensive description of the distribution and abundance of these organisms

in this important river system. During May 1974 to May 1975 we expanded our sampling coverage and collected a total of 580 benthos samples from 167 stations throughout the river system downstream from Sault Ste. Marie. Analysis of about 70% of these samples confirmed that burrowing mayfly nymphs (mostly *Hexagenia* and *Ephemera*) and caddis fly larvae (mostly *Phylocentropus*, *Polycentropus*, *Oecetis*, *Mystacides*, and *Triaenodes*) were indeed present in substantial numbers throughout the river system, except in the North Channel of the river from Sault Ste. Marie downstream for a distance of about 15 miles. In that portion of the river, oil was visible on the surface of the water and in the bottom samples, and none of the samples contained mayfly nymphs or caddis fly larvae. Analysis of the remaining samples will permit us to describe more precisely the downstream extent of the heavily polluted area.

Biological Effects of Heated-water Release for Ice Suppression in Navigation Channels. — The U.S. Army Corps of Engineers conducted a small-scale test in January-April 1976 to determine the feasibility of using waste heat from a steam-electric power plant to reduce ice cover in a shipping channel. The test site selected was about 1 mile off the mouth of the Saginaw River in lower Saginaw Bay, Lake Huron. Heated water from the Karn-Weadock power plant discharge canal was pumped through a submerged 800-foot diffuser pipe positioned along the edge of the navigation channel.

To provide a basis for evaluating the effects of the heated-water release on the important biota at the test site, the Great Lakes Fishery Laboratory conducted a study funded by the Corps, from November 1972 to May 1976. Benthic invertebrates were sampled before and after the test with a Ponar grab. The fish population at the test site was sampled before, during, and after the release of heated water. Gill nets, trawls, and small (2 x 2 x 4 feet) hardware-cloth funnel traps were used when the site was ice free; when there was ice cover, only the funnel traps were used.

Pollution-tolerant oligochaetes and midge larvae were the principal benthic organisms present in the samples. No changes in the abundance of these dominant organisms that could be attributed to the release of heated water at the test site were observed. Most of the observed differences in the kinds and numbers of benthic invertebrates throughout the study area appeared to be related to differences in substrate type. Preliminary evaluation of the fish-sampling data also failed to reveal any

major changes in the kinds and numbers of fish in the test area that could be attributed directly to the release of heated water. Large changes were observed in the fish population on several occasions, but these were accompanied by strong currents and high turbidity and appeared to be related to the volume of discharge from the Saginaw River.

The absence of observable effects of the release of heated water on benthic invertebrates and fish at the test site is not surprising because the test was of short duration, the release of heated water was intermittent, the maximum excess temperature measured in the test area was never more than 1° C, and the Corps apparently avoided pumping chlorinated water to the test site. In addition, the influence of the polluted Saginaw River discharge on the test site probably tended to preclude detection of any subtle effect of the heated water on fish and benthos.

Effects of Food Availability and Temperature on Food Competition Between Young-of-the-year Perch and Alewives. — The effects of small temperature increases on fish and other aquatic organisms that inhabit littoral waters receiving waste heat from power-generating plants have not been measured. Information developed at the Great Lakes Fishery Laboratory and elsewhere suggests, however, that even small increases in water temperature, especially during the warmer months of the year, create locally undesirable conditions for some native fauna. Under the hypothesis that the functional efficiency of some species may be so impaired by elevated temperature as to cause them to desert the affected portion of their range or suffer reduced survival, the Laboratory is conducting controlled experiments to observe the effects of temperature increases on the availability of food to, and competition for food among, prey and predator species.

More specifically, these studies, being made at the Laboratory's Hammond Bay Biological Station, are to determine the effect of food availability and ambient temperature on the feeding rate, food selectivity, growth, and survival of mixed- and single-species populations of young-of-the-year alewives and yellow perch. The young yellow perch and alewives are being used because they have similar optimum temperatures, are planktivorous, and occupy the same habitat. Moreover, the abundance of perch and alewives, in Lake Michigan for example, also appears to vary inversely, suggesting a significant degree of competition between the two species in that lake.

In our early tests, single-species populations of young-of-the-year perch and alewives (total of 480 fish of each species) were acclimated to 10°, 15°, 20°, and 25° C, and fed mixed zooplankton that included *Daphnia magna*, *D. pulex*, *Bosmina longirostris*, and small copepods at a level of 0.5, 1.0, 2.5, or 5.0% of their body weight. Examination of stomachs from perch acclimated to 25° C indicated that they preferred the largest zooplankton, *D. magna*, to the smaller plankters, despite the greater abundance of the smaller plankters in the food mixture. However, the perch acclimated to 10° C were relatively inactive and unselective feeders with regard to size and species of prey organisms. Forty-six percent of the food ingested by perch acclimated to 10° C consisted of the small prey organisms, *Bosmina* and copepods, whereas these smaller plankters made up only 3% of the stomach contents of perch acclimated to 25° C.

Analysis of 50 of the 480 preserved alewife stomachs indicated that alewives fed more extensively on smaller plankters than did young perch — suggesting that the alewives may have a competitive advantage over perch when the food supply consists primarily of organisms smaller than *D. pulex*.

Effect of Sublethal Heat Shock on Great Lakes Zooplankton. — Relatively large quantities of zooplankton inhabiting nearshore waters of the Great Lakes pass through power plant cooling systems. Available information indicates that about 7% of entrained zooplankton is killed by mechanical damage and heat stress. Little is known of the effect on the remaining 93% of the entrained population that apparently survives, although one suspected effect of heat stress on zooplankton is a reduction in reproductive potential due to a lengthening of the time between generations.

To determine experimentally if the reproductive potential of zooplankton populations is reduced by sublethal heat shock, we acclimated laboratory populations of typical zooplankters, *Daphnia magna* and *D. pulex*, to 10°, 15°, 20°, or 25° C; exposed them suddenly to temperatures 10°, 15°, or 20° C above their acclimation temperature for 2 minutes; and then cooled them quickly to their previous acclimation temperature. Shock temperatures and the postshock cooling rate were selected to approximate those that would be experienced by a planktoner during passage through the cooling system and discharge plume of a large nuclear-fueled power plant on the Great Lakes. We monitored test and unshocked control populations after 9, 18, and 27 days (or until the density of

organisms in a test chamber limited population growth) and recorded numbers of individuals, their relative sizes, number of eggs per female, and production of ephippia (capsules containing winter eggs).

Exposure to shock temperatures 15° and 20° C above the acclimation temperature was lethal for *D. magna* and *D. pulex* acclimated at 25° C. At lower, nonlethal shock and acclimation temperature combinations, heat-shocked populations of both species were usually smaller than control populations. The difference between heat-shocked and control populations of *D. magna* acclimated at 10°-25° C became apparent 9 days after heat shock; for *D. pulex* the difference became apparent after 12, 18, and 22 days for groups acclimated at 10°, 15°, and 20° C, respectively, and shocked at temperatures 10°-20° C above the acclimation temperature. *D. pulex* acclimated at 25° C and shocked at 10° C responded by increasing the production of ephippia. These results suggest that *D. pulex* has a longer generation time than *D. magna* and thus would be more adversely affected than *D. magna* by sublethal heat shock received during entrainment.

Nutrient Cycling and Plankton Productivity in the Nearshore Waters of Lake Huron. — Intensive limnological studies were conducted from 1973 to 1976 in the nearshore waters and tributary streams of northwestern Lake Huron near the Hammond Bay Biological Station to examine the relationships between seasonal changes in nutrient availability and plankton abundance, and to determine the influence of atmospheric fallout and land runoff on the nutrient dynamics of the nearshore waters. Knowledge of nutrient-plankton dynamics in this portion of Lake Huron, which appears to be relatively undisturbed by man's activities, will provide a basis for interpreting changes observed in other parts of the Great Lakes that have been heavily affected by man.

Sampling in the nearshore waters of the Hammond Bay ecosystem (1973 to 1975) revealed that phosphorus concentrations were consistently low throughout the year (<10 µg/l), suggesting that primary productivity in these waters, like that in other unpolluted portions of the Great Lakes, is phosphorus limited. Concentrations of nitrate and silica, two other nutrients known to regulate plankton productivity, were highest in the spring (280 and 2,500 mg/l, respectively) and lowest during the summer (150 and 600 mg/l, respectively). Data obtained weekly (July 1975-June 1976) by sampling six streams entering Hammond Bay indicate that high nitrate and silica concentrations

in tributary runoff during February and March contribute significantly to the high spring concentrations of nitrate and silica in nearshore Hammond Bay waters.

Examination of phytoplankton in samples collected from the nearshore waters of Hammond Bay (March 1973-July 1975) has shown that diatoms (largely *Tabellaria fenestrata*) were the most abundant group numerically and volumetrically during the spring of 1973; other taxa made up less than 5% of the total number and volume. Maximum density of algal cells observed thus far was only 234/ml, which is considerably below the average densities of 1,000 to 4,000/ml reported by other investigators for open Lake Huron and Saginaw Bay in southwest Lake Huron, respectively. These results support our hypothesis that the nearshore waters of Hammond Bay are indeed oligotrophic.

Crustacean zooplankton in samples collected 5 days per week from June 1973 to July 1975 in Hammond Bay have now been identified and counted. Computer plots of geometric mean densities of various taxa and total zooplankton by day, week, and month reveal that zooplankton density was highest in midsummer (2.4 per liter) and lowest in late winter and early spring (0.1 per liter), as has been reported in the literature for the open waters of Lake Huron and for Georgian Bay in northeast Lake Huron.

All of the results obtained thus far are consistent with the expected nutrient-plankton relations in an unpolluted portion of the Great lakes.

Forage Requirements of Lake Trout and Coho Salmon. — Work continues on the development of information required in formulating energy budgets for salmonids in Lake Michigan. These budgets, when completed, will permit the prediction of forage needs in relation to the capacity of the lake's forage base to support growing salmonid populations.

The energy necessary for the routine metabolic activity of lake trout was determined by measuring the oxygen consumption of 503 lake trout (174 tests with 1, 3, or 20 fish) forced to swim in a tunnel respirometer at various controlled speeds (10 to 60 cm per second) and temperatures (3.5° to 18.0° C). The oxygen consumed by these fish was converted to caloric equivalents by incorporating a standard oxycaloric coefficient into the energy budget.

Linear regressions describing the relation between the logarithm of oxygen consumption and swimming speed have been computed for each of the five temperatures tested. The standard

metabolic rates or resting metabolic rates were estimated by extrapolating the regression lines to the point of zero activity (swimming speed zero). Since these extrapolations require only a short extension of the regression lines to the Y-intercept, the estimated rates give a reasonably good approximation of the maintenance oxygen requirements of the fish. The logarithm of the rates increases linearly with temperature from a low of 39 mg/kg per hour at 3.5° C to a high of 129 mg/kg per hour at 18° C, or about a threefold increase. The relations between rate of oxygen consumption and fish weight, activity level, and temperature were described by a multiple regression equation, and the equation can be used to predict either the oxygen or caloric requirements of lake trout whenever their weight, swimming speed, and ambient temperature are known.

Effects of Temperature on Sperm Quality in Great Lakes Fishes. — Attraction of fish to heated waters from power plants has long been considered potentially detrimental to the normal life cycle of fish. Although considerable research has been done to show how temperature affects the rate of development and hatchability of fish eggs, little is known about the temperature requirements of fish sperm and the effects of temperature alteration on their viability and mobility.

Major problems in performing studies with sperm of coldwater fishes are the lack of adequate experimental techniques and the short and infrequent periods in which viable sperm may be observed. To assist in the development of improved techniques for testing sperm viability, we have been using the flagfish (*Jordanella floridae*) — a warmwater species that matures in 6 to 8 weeks after hatching and spawns continuously throughout the year — as a source of viable sperm.

As part of preliminary testing, it was necessary to establish the thermal tolerance of flagfish. Using previously described techniques, we determined that flagfish have an ultimate upper lethal temperature of 39.7° C and a broad range of thermal tolerance.

TUNISON LABORATORY OF FISH NUTRITION

Alternate Sources of Biotin for Lake Trout. — In a study designed to determine the suitability of corn distillers solubles (CDS) as a biotin source for

trout, growth of trout fed CDS (compared with those fed crystalline biotin), and the microbiological assays for dietary biotin, showed that the dietary CDS contained much less biotin than published values indicate, and that it appears to be a poor source of this vitamin. The testing of other feedstuffs for biotin is needed. The results also confirmed earlier indications that lake trout need no more than 0.1 ppm dietary biotin. This level is well below the recommendation of the 1973 National Research Council for optimum growth and feed utilization of salmonids.

Dietary Interrelations of Biotin and Pantothenic Acid in Lake Trout: New Deficiency Signs. —

Results of a feeding study, conducted to further characterize dietary biotin and pantothenate deficiency signs in lake trout, showed heretofore unreported symptoms in addition to the deficiency signs classically associated with the feeding of diets lacking these two vitamins. A simultaneous deficiency of both biotin and pantothenate caused a slower growth rate, more severe anemia and atrophy of acinar (enzyme-producing) pancreatic cells, and a higher death rate than occurred in trout fed a diet deficient in either biotin or pantothenate alone. The simultaneous lack of dietary pantothenate and biotin diminished the degree of fatty infiltration found in livers of trout lacking only dietary biotin. Whereas a total necrosis of kidney tubules occurred in only the pantothenate-deficient trout, intertubular deposits of glycogen were found in the kidneys of only the fish lacking biotin.

Lake Trout Respond Negatively to Graded Levels of Dietary Fiber. — A study undertaken to measure the effects of diluting a practical type of diet with up to 32% cellulose showed a linear suppression of growth and feed use as the level of dietary cellulose increased. The higher levels of cellulose diminished digestible and metabolizable dietary energy and body fat. These results show not only that the dietary fiber is poorly used by trout, but also that it adversely affects fish growth and use of other nutrients.

Nutritionally Induced Cataracts in Lake Trout. — Feeding diets containing a commercial soy protein isolate as the only protein induces a high incidence of cataracts. Therefore, the effect of supplementing this diet with amino acids (methionine and lysine), L-ascorbic acid, or minerals (calcium and phosphorus, or chromium) on the development of cataracts was studied. The feeding of supplemental methionine and lysine prevented cataracts, but the use of supplemental minerals or ascorbic acid did not.

Inland Fisheries and Reservoir Management

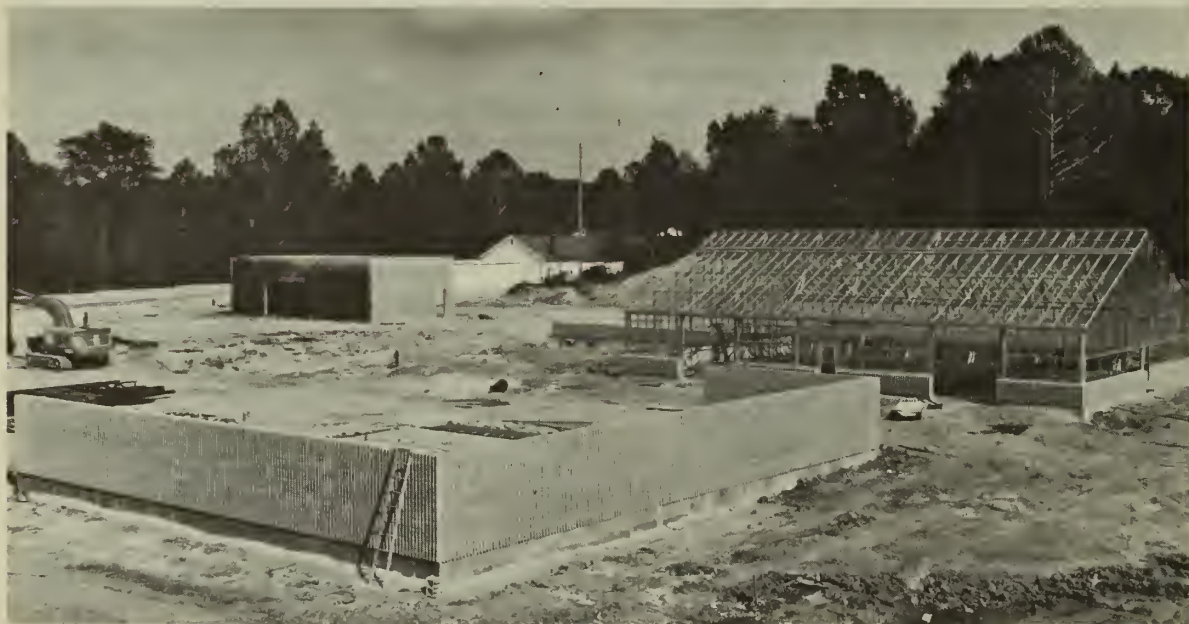
EASTERN FISH DISEASE LABORATORY

Bacterial Gill Disease. — This is an infectious disease very similar to pneumonia of warm-blooded animals. It is a major cause of mortality among young cultured salmon and trout. Past investigations, as well as field observations, have shown that one type of waterborne bacterium is usually present and therefore may play an important role in causing the condition. However, all attempts to transmit gill disease with cultures of this bacterium have been unsuccessful. During the year, gill disease was induced in Atlantic salmon by crowding them and reducing their supply of water. The disease was then transmitted to young rainbow, brook, and cutthroat trout simply by supplying the trout with effluent water from the affected salmon.

One means of preventing infectious diseases

among cultured fishes is to eliminate contact between the pathogen and host. Many hatcheries must use stream water harboring carrier fish. Ultraviolet irradiation is used at several hatcheries to disinfect incoming water, but dosages required to kill fish pathogens are not yet known. Five important bacterial fish pathogens were tested for their susceptibility to several different levels of ultraviolet (UV) irradiation. Levels of 13,300-29,000 units (microwatt seconds per square centimeter) killed 99.96-100% of all organisms in clear water or in water containing particulate matter. Dosages as low as 4,450 units also effected a 99.83-100% kill.

The practicality of using UV in preventing actual infection was demonstrated by irradiating water that had passed over trout with furunculosis. Susceptible test fish failed to develop the infection, whereas 100% of the fish exposed to the



Construction of the new National Fish Health Laboratory at Leetown, West Virginia, is proceeding on schedule. In the immediate foreground walls of the concrete tank pad have been laid. A completely glass-enclosed warmwater fish pond is shown on the right. A masonry garage (background) will abut the main laboratory, which was started in late 1976. Photo by H. M. Stuckey.



Participants of the biennial comprehensive course on fish diseases are shown in the training laboratory. Six resident and six visiting scientists lecture and provide practical laboratory experience during a 5-month period. *Photo by H. M. Stuckey.*

nonirradiated water died. Filtration of water before irradiation improved the efficiency of UV by removing particles that shield bacteria from the lethal UV. These results indicate that low UV dosages (13,300 units) kill bacterial pathogens naturally present in hatchery water supplies.

Egg Transmission of Fish Diseases. — Some fish diseases are transmitted from parent to offspring in the eggs. This route of transmission was tested with viral infectious pancreatic necrosis (IPN) and bacterial furunculosis. The IPN studies were carried out jointly by the Eastern and Western Fish Disease Laboratories. Eggs and sperm obtained from brook trout with IPN were divided between the two laboratories. The resulting fertile eggs were

further divided into four groups at each facility, two being disinfected with an organic-iodine complex and two remaining untreated. At both laboratories trout began to die soon after hatching, and IPN was eventually diagnosed in 7 of the 8 groups. The results show that IPN was transmitted with eggs and sperm and that disinfection with the iodine complex did not prevent the disease. Similar studies with furunculosis showed that the causative agent could not be detected either in eggs or sperm from carrier fish nor in their offspring. The inference is that, in contrast to IPN, furunculosis is not transmitted by eggs. The work will be repeated.

Disease Diagnoses. — Fish health specialists make conclusive and sensitive diagnoses of diseases



FISH HEALTH NEWS is a quarterly communication that is distributed as a service to diagnosticians and researchers by the Eastern Fish Disease Laboratory. Now in its 5th year of printing, circulation is expected to triple as individual requests can be honored. Photo by H. M. Stuckey.

that occur in hatcheries or in natural populations. Serodiagnoses with specific antisera are the most rapid and accurate methods known, but they require standardized biological reagents, specific antisera, and antigens. In human and veterinary medicine, standardized antigens and specific antisera are produced by, and are available from, centralized Federal laboratories, and the more common reagents are even available commercially. The Eastern Fish Disease Laboratory provides the counterpart service for fish health diagnosticians. Antisera are produced by immunizing rabbits with specific fish pathogens, after which the rabbit blood serum is processed, tested, and freeze-dried for distribution to qualified diagnosticians and researchers. Shipments are accompanied with recommended procedures for reconstituting and using the products. Forms are also supplied to be filled in with the users' results. During the report year, over 300 requests for these materials were received and the reagents shipped.

At present, stocked items include 35 different antisera and antigens.

Present research is concentrated on continued improvement of the antisera and antigens, particularly on finding more effective methods of antigen preparation and rabbit immunization. In addition, larger batches of reference antigens are being processed to better standardize serodiagnostic procedures.

Whirling Disease in Salmonids. — This disease is caused by *Myxosoma cerebralis*, a myxosporidan parasite accidentally brought into North America some 20 years ago. Severe infections of *M. cerebralis* result in death, and mild infections cripple or otherwise impair the host fish. Consequently, the parasite is a significant factor both in the propagation of trout and in their later survival in the wild. Methods have recently been developed for freeing the parasite from host cartilage and for concentrating it. For such diagnostic work, stained spores are used as markers to measure the efficiency of release and concentration. A comparison of 11 dyes showed that silver nitrate provided the most lasting spore stain; the distinctive coloration persisted through

processing and later storage for 1½ years.

Serological methods, particularly the fluorescent antibody technique (FAT), provide positive identification of *M. cerebralis* and the most sensitive and earliest detection. Using FAT, we found evidence of infection 17 days after experimental exposure. The FAT is now carried out on a routine basis. The procedure has, however, revealed heretofore unknown biological relationships between *M. cerebralis* and other myxosporidians. In addition, FAT is being used to learn the life cycle of the parasite.

Eel Virus. — The description of the eel virus, EV-1, has been completed and a manuscript has been written. Electron microscopy has established the size and shape to be similar to human influenza virus, a fact consistent with the findings of virological tests used in describing viruses.

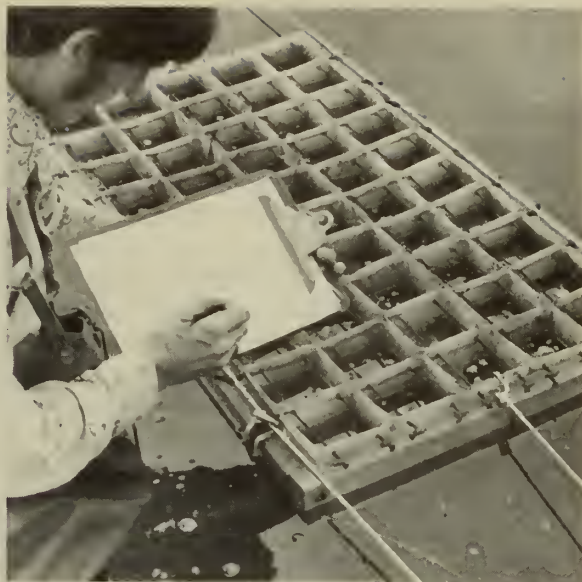
Among mammals, females transfer protective immunity to newborn offspring by colostrum, a special product in milk that is produced following birth. Such passive protection was demonstrated in rainbow trout fry that had been injected with adult brook trout antibody. The young rainbow trout were protected against levels of IPN virus that killed nearly 60% of the unprotected fry. The results have application in fish husbandry as a possible means of preventing loss. Further studies are under way.

FISH CONTROL LABORATORY

Registration of Fish Toxicants. — The Fish Control Laboratories continued studies on techniques to control fishes. Antimycin is an effective fish toxicant that has been widely used to reclaim waters for sport fishing. Although a registration currently exists for this use, the data in hand are not adequate to support the reregistration required by EPA.

Environmental effects of chemical applications are a continuing concern to ecologists and are a vital part of the data requirements for registration of any compounds. Unexplained mortalities of clams are sometimes observed several weeks or months after waters have been treated with antimycin. The effects of short- and long-term exposures of clams to the toxicant were measured in tests conducted at the Southeastern Fish Control Laboratory.

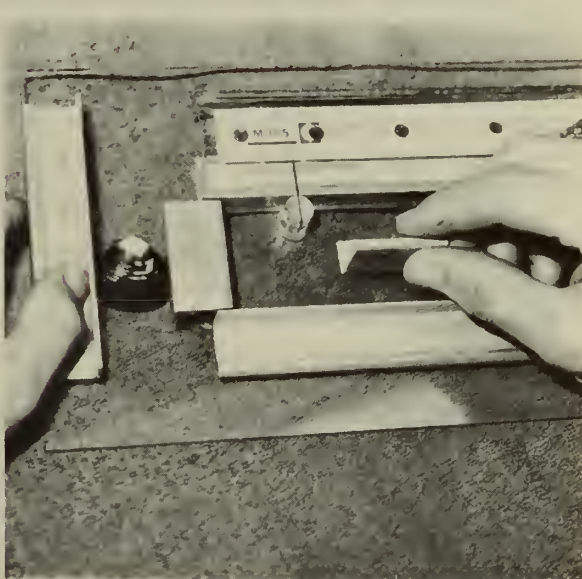
There were no significant increases in the mortality of selected species of clams of 2 µg/l for 12 hours or 50 µg/l for 24 hours in test chambers or to 2 µg/l indefinitely under pond conditions.



Long-term survival studies on clams are conducted in floating compartments to detect delayed mortality after exposure to antimycin, a fish toxicant. Photo by J. H. Chandler, Jr.

However, long-term exposures at concentrations of 5 to 20 µg/l produced delayed mortality.

In studies with the Asiatic clam, *Corbicula* sp., we explored the effects of time and concentration on mortality. All clams treated and left in antimycin solutions in test chambers for 30 days before



The Asiatic clam, *Corbicula leana*, is an unwelcome exotic that is becoming established in many U.S. waters. Measurements of the shell are used to determine growth rates and to identify year classes. Photo by J. H. Chandler, Jr.

transfer to untreated ponds died. On the other hand, clams exposed for 24 hours and then transferred to untreated ponds survived. Animals exposed to continuous low levels (3.6 $\mu\text{g/l}$) of antimycin for 30 days died shortly after their removal to untreated ponds, but clams treated at 50 $\mu\text{g/l}$ for 24 hours had much lower mortality when handled in a similar way.

Use patterns in the treatment of waters for fish removal indicate that clams are unlikely to receive more than a 24-hour exposure to antimycin. Although changes in habitat that may result from the removal of fish could adversely affect clams, it appears that antimycin is not a direct cause of mortalities observed in treated rivers.

Radio-labeled antimycin was used to study the breakdown of this compound. Exposure of solutions at pH 5 to longwave ultraviolet light for 48 hours resulted in no significant degradation. Methanolic solutions were exposed to UV light for up to 24 hours and studied by exposure to X-ray film. Degradation was slow — only 64% after 24-hour exposure to UV light. Five as yet unidentified degradation products were observed.

The hydrolysis of ^{14}C -antimycin at pH 9.2 was also studied. All samples degraded rapidly. Less than 50% of the parent compound remained after 4 hours and only 12% or less after 5 days. Five degradation products were noted, one of which was presumed to be blastmycic acid.

Although laboratory materials can be analyzed with fair resolution, problems were encountered when tissues from exposed fish were checked for residue levels. Residue methodology and data represent major voids in the available information base on antimycin. Without such data, re-registration is unlikely.

Alternate fish toxicants are being studied as adjuncts to, or potential replacements for, the currently used materials. One promising candidate, coded GD-174, has shown a marked toxicity to carp but not to other warmwater fishes. In laboratory tests conducted in small pools, 0.5 $\mu\text{l/l}$ killed all carp without loss of bluegills, largemouth bass, or channel catfish. All rainbow trout stocked in the pools were killed. Studies are under way to delineate the effects of algal blooms, plant growths, and turbidity and to determine the toxicity of GD-174 to other species of fish. If the selectivity observed in laboratory tests extends to field situations, GD-174 promises to be an effective new tool for the control of carp in fishery management.

Currently available formulations of GD-174 lack uniformity of activity and have only a short shelf

life. Both characteristics are under study and preliminary results suggest that neither will be a major problem.

Thanite, an experimental fish-collecting aid, causes fish to float on the surface in a comatose condition. Fish transferred to clean, aerated water quickly recover. It has been postulated that Thanite could be used to selectively collect predator species or to collect desired brood fish.

Field studies demonstrated that yellow perch, redear, bluegills, walleyes, crappies, largemouth bass, and redhorse can be collected with survival rates up to 99%. Golden shiners, white suckers, bullheads, and northern pike are less easily collected and may have lower survival rates. No northern pike recovered after transfer to clean, aerated water.

Degradation or loss of activity occurred in 8 days at temperatures of 18° to 23° C and pH's of 4.9 to 6.6.

A pond treated in October 1974 was studied over the ensuing 2 years and collections were made to assess possible environmental effects. Planktonic crustaceans were reduced by 80 to 90% 7 days after treatment. Six months after treatment, microcrustacean populations began to recover and continued to increase for 1 year. However, *Daphnia* numbers did not return to pretreatment levels and *Diaptomus* disappeared and did not return. Benthic populations were not significantly altered by the chemical application.

A method for the determination of Thanite residues and metabolites in water, mud, algae, and fish tissue was developed. Residues were found for 3 weeks but not thereafter. A major metabolite found in fish tissue has been identified as a thioether of Thanite. Isoborneol also occurs as a residue in fish tissue.

Registration of Therapeutants for Fish. — Formalin is widely used for the treatment of external parasites of fish. Studies to determine ecological effects revealed that fish in treated ponds survived well, spawned, and produced a normal crop of young-of-the-year fish. Oxygen levels were temporarily depressed but returned to normal in 5 days under pond conditions. Benthic organisms in treated ponds were not affected.

Applications made in plastic pools having a dense algal bloom indicated that the formalin may kill the algae and that the combined effects of chemical depression of the oxygen level, coupled with the oxygen reduction caused by decaying algae, may result in an oxygen depletion and fish mortality.

Malachite green, a parasiticide and fungicide, is suspected of having physiological effects on fish and fish eggs. Rainbow trout fingerlings were continuously exposed to a sublethal concentration in flow-through systems. After 28 days no marked alterations could be detected in the blood chemistry of treated fish.

Laboratory tests confirmed empirical evidence that the toxicity is related to concentration, length of exposure, and temperature but that it is not affected by pH or water hardness.

Hatching was delayed in eggs of rainbow trout exposed to malachite green at 1 mg/l for 1 hour daily, 3 mg/l for 1 hour every other day, or 5 mg/l for 1 hour weekly. The incidence of abnormalities was 2.5 to 7 times that of untreated eggs, and growth rate of all fry from treated eggs was reduced.

Bacterial gill disease is a continuing problem in the production of trout and salmon and is particularly troublesome in hatcheries rearing Atlantic salmon. Furanace, a nitrofuran drug, is a therapeutant that effectively controls bacterial gill disease. However, the drug is not registered for use on food fish or on hatchery fish that eventually might become food fish.

Studies at the Fish Control Laboratories demonstrated that the activity of Furanace is not affected by pH or water hardness. Rainbow trout exposed to recommended use pattern rates for three consecutive days exhibited no mortality or abnormal behavior. The toxicity to trout increases, however, with rising water temperatures and increased exposure times. Freshwater prawns, snails, and Asiatic clams were not affected by concentrations of Furanace up to 20 mg/l for 1 hour. Other studies indicated that Furanace solutions retain their activity for over 6 weeks. Consequently, effluents from hatcheries where Furanace is used are likely to contain significant concentrations of the compound.

If Furanace could be removed from hatchery effluents, concern over possible environmental contamination would be greatly reduced. Data developed at the Fish Control Laboratories show that Furanace can be effectively removed by activated carbon filtration. In cooperative studies with the Green Lake National Fish Hatchery, Ellsworth, Maine, a prototype filter system effectively removed the drug from treated water under hatchery production conditions without stressing the treated fish, and with little inconvenience to hatchery operations. Effective removal techniques will greatly reduce concerns over environmental contamination resulting from the

use of Furanace and should expedite amended registration of fishery uses in the control of bacterial fish diseases.

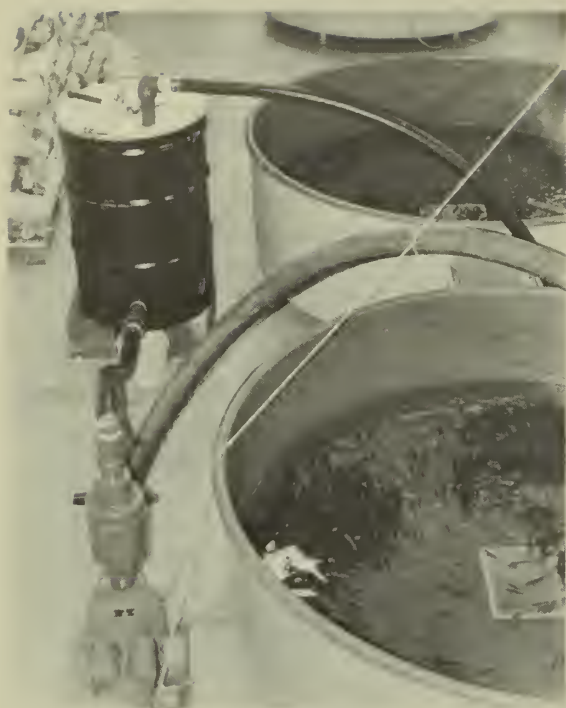
Unexplained variations are observed in the responses of fish to fishery chemicals. It has been hypothesized that the presence of other environmental contaminants may greatly affect the toxicity of treatments. To test this hypothesis, we divided a lot of rainbow trout into three groups, and exposed one group to 0.1 $\mu\text{g/l}$ of the PCB, Aroclor 1254, and another to 0.01 $\mu\text{g/l}$; the third group served as untreated controls. After 30 days of exposure, whole body residues were 0.28 $\mu\text{g/g}$ and 2.31 $\mu\text{g/g}$ for the respective exposed groups and their sensitivity to several fishery chemicals was then determined in standard toxicity tests. Included in the tests were rotenone, antimycin, GD-174, TFM, formalin, malachite green, Furanace, MS-222, copper sulfate, and 2,4-D:DMA.

Most of the chemicals were unaffected by the presence of the PCB residues, but both groups of exposed fish were more resistant than the controls to antimycin and malachite green, and were more sensitive than the controls to rotenone and 2,4-D.

Registration of Anesthetics for Fish. — Anesthetics used to sedate or narcotize fish must also be registered by the Food and Drug Administration. Materials submitted with applications for registration lacked data on residue persistence. Studies during the year indicated that no residues of the two most commonly used anesthetics, quinaldine sulfate and MS-222, were present in fish tissues 24 hours after removal of the fish from the anesthetizing solutions. When the two compounds were used together at recommended levels, no residues were found after 24 hours. The results provide assurance that fish can be effectively anesthetized without concern about undesirable or potentially hazardous residues in treated fish. This finding is significant because many brood fish and fingerlings are exposed to anesthetics in the normal hatchery production of fish for public waters.

Counteraction and Removal of Chemicals Used in Fisheries. — A prototype filter system developed at the Fish Control Laboratories continues to find application beyond its original drug removal purpose. Use of other filter media in the system greatly expands its potential use. One such use would be for the removal of ammonia from hatchery effluents.

Three resins (XAD-7, Biosorb, and pH filter resin) and clinoptilolite, a form of zeolite, were evaluated for their effectiveness in removing ammonia from water. A 2-liter stock solution of



A prototype filter system developed at the Fish Control Laboratory effectively removes most chemicals used to control fish diseases without stressing the animals. *Photo by L. L. Marking.*

10 mg/l NH_3 as N was filtered through a 15-cm bed of each. The effluent was sampled at selected volume intervals and ammonia concentrations were determined by specific ion electrode analysis. Clinoptilolite was the most effective adsorber, removing all detectable ammonia from the 2-liter stock solution. Biosorb and XAD-7 were also effective adsorbers, but detectable levels of ammonia were present in the effluent after 600 ml had passed through the filters. The pH filter resin, the least effective adsorber, removed almost no ammonia.

In separate studies, the effects of water pH on adsorptive capacity of clinoptilolite for ammonia were evaluated. Clinoptilolite was about 60% less effective for removing ammonia from water of pH 6.5 than from water of pH 9.5. Although clinoptilolite has a strong affinity for ammonia, it does not remove nitrates or nitrites, both of which are potentially toxic to fish.

The effects of temperature, water hardness, and pH on the toxicity of nitrate to rainbow trout, channel catfish, and bluegills were determined. Toxicity of nitrate nitrogen to these species increased with exposure time, and generally was not affected by the temperatures, hardnesses, or

pH's, but it was significantly more toxic to rainbow trout in soft, acid water of pH 6.5 than in alkaline water of pH 9.5.

The toxicity of nitrite nitrogen to rainbow trout, channel catfish, and bluegills at selected temperatures, hardnesses, and pH's was determined. In rainbow trout, the toxicity of nitrite was not affected by the different water temperatures, but was significantly increased in soft waters and in water of low pH. In channel catfish, toxicity was not significantly affected by water temperature or pH, but it was significantly greater in soft water than in hard water. In bluegills, toxicity was significantly greater in warm than in cold water and in soft, acid water than in neutral or alkaline water. Under the same test conditions, nitrite was 145 times more toxic to rainbow trout and 233 times more toxic to channel catfish than it was to bluegills.

FISH FARMING EXPERIMENTAL STATION

Biological Filters to Remove Fish Growth Depressants. — Metabolic excretions and other growth depressants limit the reuse of water in fish production. However, the reuse of part or all of the water in which fish were previously cultured conserves this limited resource for higher priority programs; also, pollution of the environment is reduced when organic contaminants are removed from the discharge water.

Passive systems that take advantage of natural heat and oxygen are desired, because they require little additional energy. Of the various filter types tested, water hyacinth, which has caused so many problems in southern warmwater lakes and rivers, has been found to efficiently remove organic waste metabolites, heavy metals, and other waterborne contaminants.

A filter system that shows considerable promise in water reuse consists of tube settlers. This system has an advantage over aquatic plants in that no sunlight is required, and it is therefore adaptable to indoor facilities. Our analytical data show that the tube settlers are 3 times more efficient in removing suspended solids and over 20 times more efficient in removing settleable solids than are water hyacinths. Thus, this filter system appears to be satisfactory for oxidizing soluble metabolites in culture systems.

Draining Methods for Decreasing the Amount of Settleable Solids in Effluents from Fish Ponds. — Controlled draining should limit the amounts of

settleable solids in pond effluents. However, no documented studies on the effect of controlling the flow from bottom-drain fish ponds are available.

To obtain meaningful information on which EPA might base discharge criteria, we stocked test ponds with carp, a bottom "rooter" that tends to keep a pond turbid. The drain was opened at preselected intervals to obtain samples of effluent.

As the drain opening (flow rate) was increased, the maximum instantaneous values for settleable solids usually increased, but at mean flow rates above 723 l/min these maximum values decreased. Controlled draining apparently decreased the settleable solids. However, the total settleable solids discharged in 10 minutes usually decreased as the flow rate increased. Flow rates of 88 l/min or more were of sufficient velocity to move solid particles of the density occurring in this pond. A lower flow rate probably would not carry particles from this pond; however, the use of an extremely low pond discharge rate as a method for reducing solids in effluent would not be practical in intensive fish culture because of the long time that would be required to drain large ponds.

Management Methods for Removing Particulate Matter in Effluent from Fish Ponds. — The production of warmwater fish in earthen ponds no doubt affects the water quality and aquatic life in streams receiving the effluent; however, little is known about the quantities of solids generated in intensive fish culture. Such information on the type and amounts of solids produced by the various fish species in the different culture programs would permit the establishment of control methods. The manager could then comply with EPA effluent regulations and also meet his fish production requirements.

Fish density affects the amount of solids produced in the aquatic system, as one might suspect. However, the amount of suspended and settleable solids measured in ponds stocked and managed according to current recommendations for commercial fish production were not significantly different from those measured in fish-free control ponds. Only when stocking levels were doubled to 4,000 fish per acre were we able to detect deterioration in water quality.

We anticipated that another species, such as the grass carp, would permit recycling of nutrients, including phosphorus and nitrogen, and thus reduce the production of phytoplankton. The phytoplankton, after dying and decaying, contributes largely to the collection of materials we describe as settleable solids. This apparently occurred, as the

average production of solids was 1.7 times greater in fish-free control ponds than in ponds with grass carp. Moreover, average production of solids was slightly (but not significantly) less in ponds with grass carp than in those with channel catfish.

Results of studies not yet completed suggest that the stocking of fathead minnows with channel catfish does not decrease the production of settleable and suspended solids.

It does appear that catfish production levels affect the amount of pond solids produced, although not as much as one might guess. However, the lower amounts of solids measured in ponds with grass carp strongly suggest that the use of this species in combination with channel catfish will reduce the solids in the effluent of ponds.

Identity of the Ubiquitous Anchor Parasite, *Lernaea*. — Since 1950 the dangerous *Lernaea* that will attack any species of freshwater fish has been known as *Lernaea cyprinacea*. Researchers in the USSR have also been concerned with this parasite, and study of exchanged specimens revealed that the common American parasite is actually *L. elegans*. The other one, *L. cyprinacea*, attacks only goldfish. It is important to fish culturists to know that *L. cyprinacea* will not spread to other fish species but that *L. elegans* will. The two can be easily distinguished by the shape of the dorsal arms of the "anchor" which are T-shaped in *L. cyprinacea* and Y-shaped in *L. elegans*.

Asian Tapeworm Found in North American Fishes. — The Asian tapeworm, *Bothriocephalus gowkongensis*, has traveled with the grass carp from its original habitat in eastern Asia (Amur River) across Asia and southern Europe, and to the United States and elsewhere. In Europe it is now a serious parasite which often kills young carp. In the United States, Fish Farming Experimental Station employees found the tapeworm in bait minnows (golden shiners and fathead minnows), and workers at Auburn University found it in grass carp. The parasite is not identical to any of the known North American species and therefore is truly the Asian tapeworm. A publication describing this pathogen and methods of controlling it is being prepared.

Ovarian Parasite Found in a New Host. — The ovarian parasite, *Pleistophora ovariae*, of golden shiners has been known for 12 years. The parasite destroys developing eggs in the fish. It was recently found to occur also in the fathead minnow. The incidence appears to be low, but fish culturists wishing to avoid *P. ovariae* should keep this record in mind, to avoid transferring the parasite to a new location.

Marking Techniques for Channel Catfish. — Identification of individual fish or groups of fish is almost essential in selective breeding, physiology, and other research programs, and most fish management studies. Channel catfish are particularly difficult to mark since they do not have scales. The external application of silver nitrate, which cauterizes the skin, was compared with seven commonly used marking or tagging techniques: fin clipping; hot branding; cold branding; dye injections; and the application of Floy tags, ring tags, and dangler tags. After 4 months, mark retention was poor in all but silver nitrate and hot branding groups. Hot branding required a car battery and was the less versatile of the two methods because the blade of the branding iron was fixed. Fins had partly or completely regenerated on 80% of the fin-clipped fish. Cold brands faded rapidly and only 28% could be positively identified. Only 4% of the dye-injected fish were identifiable. All three tags caused lesions on the fish; many tags were lost, and the tags that remained were covered with algae and required scraping before the numbers could be read.

Fish branded with silver nitrate had easily distinguishable marks that have been retained for more than a year. Time and labor required to apply the silver nitrate mark are not prohibitive. Thus it appears that this technique is suitable for marking and identifying catfish.

Mollusks for Removing Growth Suppressant Factors in Fish Cultural Systems. — When mollusks were stocked in combination with channel catfish in static culture systems, the growth rate of the catfish increased over that of catfish stocked alone. This suggests that the mollusks remove growth suppressants, and thus are potentially valuable for incorporation into a practical closed fish-production system.

FISH GENETICS LABORATORY

Research at the Fish Genetics Laboratory is expected to yield two principal results: (1) a definition of the strain of rainbow trout that is best suited to meet a specific management objective, and (2) definitions of how these fish can be produced in our existing hatchery system. These objectives are approached through a variety of genetic studies as outlined below.

Strain Characterization. — Ten distinctive strains, 12 inbred lines, and 9 strain crosses are being maintained for genetic characterization.

Heritability estimates are obtained for a variety of morphological attributes (e.g., number of vertebrae) and production traits (e.g., growth), and the degree of genetic correlation among combinations of these traits is defined. Strains are also characterized by measuring the frequency of variant enzymes for each of 15 tissue enzyme systems examined by electrophoresis, and competition efficiency for use of a natural food supply is measured in terms of growth and survival. Comparisons of performance at different hatcheries, and return of fish to the fisherman after release, are obtained. Finally, each strain is ranked according to its overall efficiency, and causes for differences in efficiency are sought among the genetic differences which characterize the strain.

Although the study is now only about 20% completed, numerous strain differences have been defined.

Inbreeding Effects. — Inbreeding is the result of using small numbers of parents to produce a brood stock. This practice is apparently relatively widespread, judging by our review of brood stock management practices. Inbreeding has been shown to increase costs and decrease overall efficiency. Continuing studies have demonstrated that inbred trout are more vulnerable than outbred fish to stressful situations, such as the presence of toxicants or elevated temperature. Because inbreeding is expressed as a generalized debility, we suspect that some nutrition and disease problems may in fact be largely inbreeding problems.

Cooperative Studies. — Field tests of four rainbow trout strains supplied to the Bozeman Fish Cultural Development Center were completed. The New Zealand strain, which grew to the greatest size after release (and showed high survival), yielded the poorest growth and food conversion efficiency in the hatchery before release. This result shows that performance in the hatchery is not necessarily a good index of performance after planting.

A reverse of this situation was observed in tests of five strains at the McNenny Diet Development Center. Plant proteins were substituted for fish meal as protein sources to the extent that herring meal constituted only 6% of the diet and soybean meal 40%. Strains which showed good growth and conversion efficiency on this diet also performed best on different diets containing herring meal as the main protein source.

Blood chemistry studies on inbred and outbred trout performed in cooperation with the Western Fish Disease Laboratory indicated that blood glucose levels were higher in inbred groups than in

outbred controls. Because elevated blood glucose levels are indicators of stress, it appears that inbred trout are experiencing stress under mild conditions that are less stressful to outbred fish.

Studies on Efficient Design of Experiments. — The validity of heritability estimates is usually indicated by the magnitude of their standard errors. We have shown, however, that standard errors are in fact random variables that may assume a broad range of magnitude in repeated experiments of the same size and design. The range of magnitudes is greatest in small experiments. Poorly designed experiments can thus often yield results judged to be meaningful because of small standard errors. Size of experiments required is partly a function of the true heritability being estimated. Consequently we have defined, for different heritability levels, the size of experiments required to minimize the possibility of being misled by erroneously small standard errors.

NATIONAL RESERVOIR RESEARCH PROGRAM

Inventory of Reservoirs. — A nationwide inventory of reservoirs larger than 500 acres, compiled in cooperation with state fishery agencies, indicated that 1,493 existed in January 1976, totaling 9,774,000 acres at average water levels. Seventeen states in the southern and northwestern United States contain three-fourths of the total area. Three-fourths of the total number are in 21 states in the south, west, and north-central regions. Reservoir angling is concentrated in southern and north-central states, and California. Since 1960, about 487 reservoirs have been impounded, encompassing 3,324,000 acres — an increase of 52%. However, the pace of reservoir construction has slowed in recent years.

Current reservoir field research of the Fish and Wildlife Service is centered in Arkansas, South Carolina, and South Dakota; emphasis is on problems associated with the effects of nuclear plants, pumped storage operations, and water withdrawal from various depths on fishery resources in the impoundments and their tailwaters. A major aim of the National Reservoir Research Program involves the collection and analysis of physicochemical and biological data on large reservoirs throughout the Nation. The goal is to examine large masses of data and identify important relationships between environmental conditions and reservoir operational regimens and

the resulting biological production and sport fish abundance and harvestability.

A recent concerted effort to obtain all existing information on reservoir sport fish harvest and angler use has resulted in a doubling of the data base available 5 years ago and set the stage for marked improvements in our ability to predict harvest and angler use in planned or existing reservoirs.

Predator Fish Stocking Evaluation. — We completed the analysis of data obtained from a 2-year study of 26 reservoirs where predators (primarily striped bass and walleyes) were stocked. The field research was conducted under the auspices of the Reservoir Committee, Southern Division of the American Fisheries Society, and involved 11 State and 2 Federal fishery agencies. A method of estimating available prey-predator relations in reservoirs was developed, based on fish standing crop data derived from samples collected in rotenone-treated coves. After we determined the sizes of prey species that predators with various mouth sizes could swallow, we adjusted other species of predators to equal largemouth bass, and developed a computer program to calculate the biomass of prey available to "bass-equivalent" predators, 1 to 28 inches long, by 1-inch length groups. Results indicated that 50% of the populations sampled in August were deficient in available prey. Stocking of additional predators in these waters would be deemed inadvisable.

Average available prey/predator ratios were lowest in the standardized (bass-equivalent) 8- to 12-inch predator length classes. Greatest potential competition for food apparently occurs in this length range, which consists largely of 1- to 3-year-old predators.

The development of the computer simulation of available prey-predator relations provides fishery managers with an instantaneous estimate of the adequacy of the prey base and the advisability of stocking more predators or introducing more prey species.

Prediction of Fish Production. — To exemplify the uses which fishery management agencies may make of reservoir fish crop and harvest estimators derived from correlation and regression analysis, we undertook prediction of fish production in Oklahoma reservoirs on the basis of standing crop data from 20 of that State's 50 impoundments. Testing of 10 environmental variables revealed a strong positive influence of low storage ratio (i.e., high water exchange rate) on total fish standing crop. The crop of such bottom-feeding fishes as

carp, buffalofishes, freshwater drum, adult shad, and carpsuckers made up 70 to 85% of the total crop, and accounted for the increase in total crop as water exchange rate increased. This points to a need to intensify study of the relations between fish production and seasonal timing, volume, and quality of streamflows through reservoirs. The manipulation of water exchange rates represents a valuable fish management technique.

In the hypothetical annual production of major fishes in Oklahoma reservoirs, estimated from standing crop data, the dominance of bottom-feeding fishes was apparent. Organic detritus from vast watersheds and upstream reservoirs, plus in-lake production of bottom organisms, supplies the food required for high production of bottom-feeding fishes in reservoirs with high water exchange rates. If 40% of the total food requirement is provided by washed-in organic detritus, more management attention should be given to the watershed, to vegetation in the water level fluctuation zone, to accumulative effects in a chain of reservoirs, and to detrital materials which would enhance production of sport fish rather than rough fish.

Modeling Reservoir Fisheries. — Under a cooperative agreement with the Ecosystem Research and Simulation Division of the Waterways Experiment Station, U.S. Army Corps of Engineers, Vicksburg, Mississippi, we have developed a fishery submodel which is to be incorporated into a larger mathematical reservoir system model being designed by the Corps' Waterway Experiment Station. An extensive literature search was completed to develop: (1) food data on 78 reservoir fish species; (2) maximum specific growth rates for 46 species; (3) digestive efficiencies for various species; (4) annual, daily, and instantaneous natural mortality rates for various species; (5) regression formulas relating active and standard metabolism at various temperatures to fish weight; and (6) temperature tolerance and preference data for various species.

In addition, by using recent findings and hypotheses derived from analyses of standing crop and harvest data by the National Reservoir Research Program, we estimated the following needed inputs to the model for reservoirs in seven major drainage areas: (1) distribution of fish biomass supported by five fish-food compartments (detritus, plankton, benthos, fish, and terrestrial); (2) distribution of fish-carrying capacity and annual production among the fish food compartments; (3) carrying capacity of principal fishes; (4)

annual sport and commercial fish harvest supported by various food compartments; and (5) amount of food ingested that results in fish growth of one-half the maximum rate.

NORTH CENTRAL RESERVOIR INVESTIGATIONS

Phytoplankton Production Varies Among Four South Dakota Reservoirs. — Preliminary observations in the four lowermost Missouri River reservoirs indicated that some areas were consistently more productive than others. A better understanding of the spatial pattern of primary production and the factors responsible for change was the subject of a 2-year study. Several permanent study areas were established from lower Lake Oahe to lower Lewis and Clarke Lake, and measurements of phytoplankton standing crop, photosynthesis, and related physical and chemical characteristics were obtained at each station.

Biological conditions along this 300-mile stretch of the Missouri River reservoir system varied significantly. Areas of high production and high standing crops of phytoplankton were similar in many respects to the more eutrophic areas of the Great Lakes (e.g., Green Bay in Lake Michigan), whereas areas of low production and low phytoplankton standing crops were similar to the oligotrophic areas in the Great Lakes (e.g., offshore Lake Superior).

The spatial pattern of phytoplankton production in the four reservoirs can be explained as follows: (1) movement of water in the system is unidirectional (i.e., downstream); (2) production in the transient water mass is characteristically low and is limited by available phosphorus; (3) tributary streams entering the reservoirs are important sources of phosphorus enrichment, and a plume of increased phytoplankton production extends downstream from the mouth of each major tributary; and (4) in some areas, vertical mixing of surface water below the limit of light penetration is an added factor regulating phytoplankton photosynthesis.

Effects of Power Plant Operations on Reservoir Biology. — The effects of variable water discharges from hydroelectric power plants (peaking) on fish and plankton standing crops in downstream reservoirs are not well known. A study was conducted in 1974 and 1975 to determine the effects of peaking on the stocks of zooplankton and larval fish in Lake Sharpe, South Dakota. This reservoir

is impounded by Big Bend Dam; its headwaters extend to Oahe Dam. Plankton net sampling was conducted in the tailwaters of Oahe Dam and in the headwaters and tailwaters of Big Bend Dam.

The higher the water releases from Oahe (inflow), the lower was the number of zooplankters per liter discharged into Lake Sharpe. No similar relation was found for releases from Big Bend Dam (outflow). The observed difference was probably due to differences in the design of the powerhouse water-intake systems at the two dams.

Zooplankton standing crops in Lake Sharpe were influenced more by the total seasonal inflow than by the daily inflow cycle. Sustained high water releases from Lake Oahe in 1975, compared with those in 1974, were associated with changes in the composition of the zooplankton discharge. The percentage of calanoid copepods in the inflow from Oahe increased in 1975, the percentage of cladocerans decreased, and the percentage of cyclopoid copepods remained the same. There was a similar increase of calanoid copepods in Big Bend outflows; however, the percentage of cladocerans increased and the percentage of cyclopoid copepods decreased. The mechanisms responsible for the observed shifts in composition are not known. The number and weight of zooplankton per liter was greater in water releases from both dams in 1975 than in 1974 — probably a result of the higher reservoir water levels and discharges during 1975. The magnitude of plankton exchange is indicated by the finding that Lake Sharpe gained an estimated 5,200 metric tons of zooplankton from Lake Oahe during a single week in May 1974.

We were unable to quantitatively measure losses of fish eggs and larvae from either Lake Oahe or Lake Sharpe because of sampling problems. Eggs and larvae of freshwater drum were most abundant in collections in both 1974 and 1975. Those of carp were second in abundance in 1974, a low-water year; and yellow perch and buffalo were second and third in abundance in 1975, a high-water year.

Fish Spawning in Lake Oahe. — Knowledge of the spawning biology of fishes is basic to understanding the ecology of species and is also useful in planning the annual water regimen for Lake Oahe, a large Missouri River storage reservoir in South Dakota. In a recently completed study the timing and sequence of spawning of 17 common fishes were determined from an examination of ovaries. Changes in the mean ovary indices (ratios of ovary weight to fish length) indicated that development of eggs to seasonal spawning lasted 7½ to 10 months, depending on species, and

spawning of individual species lasted 2 to 16 weeks. Over an 8-year period (1964-71), annual variations in the date of peak spawning were usually less than a week. Although the spawning period of some species overlapped, peak spawning dates seldom coincided, and there was an established sequence of spawning among species.

The frequent occurrence of ovaries with degenerating eggs during the last several years of the study appeared to indicate that spawning conditions in this fluctuating reservoir were unfavorable for shovelnose sturgeon, northern pike, and carp.

Distribution and Abundance of Young Fish in Lake Sharpe. — Studies of the young-of-the-year fish stocks in Lake Sharpe, South Dakota, were conducted from 1967 to 1975 to determine their spatial distribution and to assess annual reproductive success by species. This work is part of a program to determine the influence of water management by the U.S. Army Corps of Engineers on reservoir fish populations. Samples were collected semimonthly from late June to early September with a standardized haul seine and a 27-foot otter trawl.

Thirty-nine fish species were collected, and the catches of both gears indicated similar trends in the distribution and relative abundance of most species. Catches were usually highest in the middle third of the reservoir, and a single, relatively small backwater area, known as Hipple Lake, accounted for about 40% of the total catch. Midsummer catches were highest for most species in all areas except the upper reservoir. Peak catches in the upper area were in late summer, probably due to upstream migration of the young fish.

Gizzard shad and yellow perch accounted for over 80% of the seine catch, whereas gizzard shad, yellow perch, black crappies, and white crappies accounted for about 90% of the trawl catch. Highest abundance of the principal species was in 1968. From 1972 to 1975, seine and trawl catches remained nearly stable, except for a 48% decline in the trawl catch from 1974 to 1975. Abundance of walleyes, the primary game fish in Lake Sharpe, remained relatively stable during 1971-75. Four species — freshwater drum, white bass, bigmouth buffalo, and smallmouth buffalo — increased in abundance during this same period. Most other species decreased.

There has been a tendency toward stabilization of the young-of-the-year fish stocks since 1971. Except for walleyes, adult predator species have been greatly reduced from earlier years, and most forage species have declined. Thus, the population

structure in Lake Sharpe is likely to continue to consist of a dominant predator (walleye) supported by a variety of young-of-the-year of other species.

Biology of Yellow Perch in Lake Sharpe. — The yellow perch is one of the primary foods of the walleye in Lake Sharpe. Because of its importance as prey, the yellow perch population was studied from 1964 to 1975 to (1) determine the characteristics of the population, including distribution, abundance, age, growth, and mortality, and (2) determine factors affecting these characteristics. Young fish were sampled with seines and otter trawls, and older fish with gill nets.

Yellow perch spawn in tributary embayments, and the young spend their first summer of life in these protected areas. They move into deeper waters of the reservoir beginning about mid-September, and some young fish tend to migrate upstream in the reservoir. Growth of the young is fastest in the lower portions of the reservoir and slowest in the upper portions. Growth rates increased in recent years and were inversely related to the abundance of emerald shiners.

The most successful year class of yellow perch was produced in 1964, the first year after impoundment of Lake Sharpe. Although spawning was successful in every year, no later year class entered the adult stock in large numbers. Adults were most abundant in 1967, but their numbers declined markedly and remained low after the 1964 year class died off. The fish are relatively short-lived; females rarely surpassed age IV or males age III. Growth rates of both males and females, which did not differ significantly, have increased in recent years. The sex ratio of adults apparently changed from about two females per male in the mid-1960's to about six females per male in the mid-1970's.

SOUTH CENTRAL RESERVOIR INVESTIGATIONS

Underwater Observations of Black Bass Reproduction. — Studies of the sympatric spawning of black basses, their nesting requirements, and reproductive potential continued in Bull Shoals Lake during 1976. Underwater observations were conducted each week from April 13 through June 3, in five study areas representing bluff and cove habitats.

Spawning by largemouth, smallmouth, and spotted bass began on or about April 3, about 2 weeks earlier than the average date of first

spawning observed since 1967. Although water temperatures were relatively high, they were still only marginal for spawning on April 6, when the temperature at 1 m depth was 13.6° C. Later lake warming was much slower than in 1975, when the rapid increase in water temperatures shortened the periods of egg incubation and larval development. The survival rates of eggs and larvae were not as high during the cooler, more prolonged spawning period in 1976. However, largemouth bass fry production was much greater than in 1975, primarily because nest densities were very high — 8.8 per 100 m of shoreline at the bluff and 9.5 per 100 m of shoreline in coves (about 4 times the highest density recorded during the previous 9 years). This great increase in the largemouth bass spawning population was presumably due to the participation of the very strong 1973 year-class. Smallmouth and spotted bass nest densities in coves were near the 10-year average. However, along the steep shoreline, spotted bass nest densities were high (15/100 m) and smallmouth bass nest densities were low (0.3/100 m).

The water level in Bull Shoals Lake at the beginning of bass spawning was about 1 m above conservation pool level and fluctuated less than 1 m during the entire spawning season, keeping the bases of shoreline willow trees flooded to a depth of 1 to 2 m. Bull Shoals Lake was extremely clear during most of the spawning season; Secchi disc transparencies ranged from 8.2 to 13.3 m (mean, 11.8 m) at the bluff, and from 3.6 to 13.5 m (mean, 7.9 m) in coves. Despite the clear water, largemouth bass nested at relatively shallow depths in coves (mean depth, 1.5 m), apparently selecting areas where partly flooded willows afforded cover. Of the largemouth bass nests in coves, 90% were beside the bases of willows where the cleaned substrate consisted at least partly of exposed roots and rootlets. Spotted bass nests in coves were frequently found in habitat and on substrate similar to that used by largemouth bass, but also in a greater variety of habitats and at a greater mean depth (2.7 m). Smallmouth bass appeared to select gently sloping rock and gravel bottoms as nesting habitat, with a mean nest depth of 2.8 m.

Incidental to the study of bass spawning were observations of crappie nesting which occurred simultaneously with that of bass in the Bull Shoals Lake study areas. Nests of black crappies and white crappies were found near the bluff, on similar substrate and at the same depth (mean, 9 m). In coves the nest depth and substrate of the two species differed: white crappie nests were in rocks and



Male smallmouth bass guarding fry in nest, Bull Shoals Lake.



Male spotted bass guarding nest of eggs in Bull Shoals Lake. Nest substrate of rocks and waterlogged branches is frequently used by this species.

gravel at a mean depth of 6.8 m, whereas those of black crappies were usually at the bases of willows or in adventitious roots on the trunks of willows, at a mean depth of 1.3 m.

Production Estimates of Young-of-the-year Shad. — Production of young-of-the-year shad in Beaver Reservoir, determined for a period June 9 to September 2, 1976 by mid-water trawling, was below average; estimates were 82 kg/ha in the upper portion of the reservoir, 23 kg/ha in the middle, and 6 kg/ha in the lower portion. Production of young-of-the-year shad was also estimated at 67 kg/ha for a 52-ha cove in the middle sector.

Two sets of comparison tests were made between a larval fish trawl developed in 1971 and a new "Tucker" trawl. Results indicated the Tucker trawl to be 3 times more effective than the other trawl for capturing young shad in June and July.

Sampling Fish Populations in Coves. — Systematic annual sampling of fish by treating coves with rotenone has been conducted annually on Beaver and Bull Shoals lakes since 1968. These long-term studies have permitted evaluation of relations between changes in fish standing crops and environmental variables. For example, fish standing crop in Bull Shoals Lake has been positively related to the volume of water flowing into the lake during the period January-July. Defining the factors which influence fish production in reservoirs and quantifying these relations is essential to effective fishery management. Cove sample data are also being used to measure variations in spawning success of many fish species,



Male black crappie guarding nest of eggs in adventitious roots on trunk of flooded willow tree in Bull Shoals Lake. Photos by L. E. Vogels.

to monitor long-term changes in the adult populations, and to define relations between predators and available prey and evaluate the adequacy of the food base.



Standing crop of fish in Bull Shoals Lake, as estimated by cove rotenone sampling, and total inflow for the period January-July, 1968-76.

Feeding and Behavior of Largemouth Bass Fry.

— In a study of the diel activity and feeding of schooled largemouth bass fry, a school of fry was observed and a sample of fry collected for stomach content analysis at 3-hour intervals for 24 hours. During most of the day, the location and configuration of the school changed little, and the fry fed continuously on limnetic zooplankters. Fry did not feed at night but remained inactive and closely aggregated in one location.

Abundance of Black Basses Estimated by Electrofishing. — Annual estimates of black basses in Beaver and Bull Shoals lakes provide a means of assessing long-term production and mortality and serve as a means of evaluating the effects of angler harvest. Mark-and-recapture estimates are made along selected sections of shoreline of each reservoir in the spring. In Beaver Lake, the estimated 1976 bass population (number per kilometer of shoreline) in the standard (downlake) study area used since 1968 was 39 for largemouth bass and 128 for spotted bass. This was the lowest estimate of largemouth bass density and the first reliable estimate of spotted bass density since the study began. In a second study area (mid-lake) in Beaver Lake, the largemouth bass population was estimated at 162/km, which was a marked decrease from 275 in 1975. In Bull Shoals Lake, the estimate of largemouth bass abundance was 87/km of shoreline, a more than twofold increase over the 1975 estimate. No reliable estimates of spotted or smallmouth bass were obtained.

Abundance and Survival of Young Black Bass in Beaver Lake. — Young black bass were sampled at frequent intervals in Coose Creek on Beaver Lake during June-August 1976, as part of an evaluation of factors influencing abundance, growth, and survival. Abundance of young largemouth and

spotted bass was estimated at the schooling fry stage and at various intervals through early August. After the schools broke up in early June, the two species were about equally abundant. A much higher rate of mortality of largemouth bass through early August, however, resulted in a marked shift in relative species abundance. Earlier studies on White River impoundments suggest that spotted bass are more successful than largemouth bass during years such as 1976, when little or no shoreline vegetation is flooded during the summer.

Cooperative Predator-Stocking Evaluation.

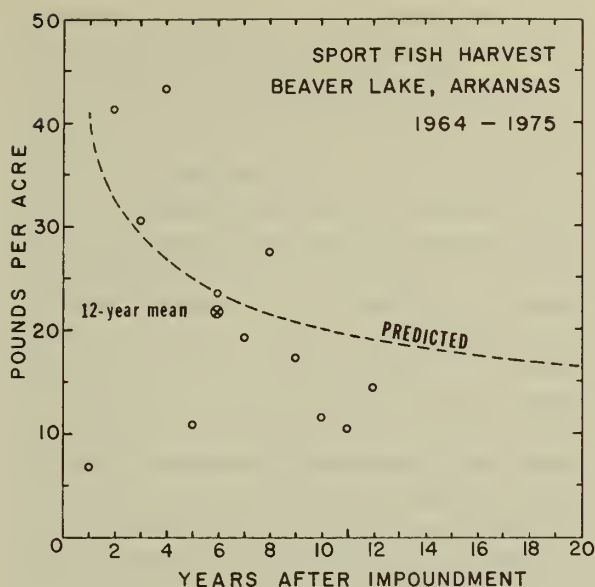
— Physicochemical and fish standing crop data from 26 southern reservoirs were analyzed as part of a predator-stocking evaluation conducted under the auspices of the Reservoir Committee of the Southern Division of the American Fisheries Society. Correlation and regression analyses were used to locate and quantify relations between selected reservoir environmental variables and fish standing crops. Water-flow related variables (e.g., outflow, volume, and storage ratio), dissolved solids, and length of growing season were generally closely correlated with fish standing crops. High volumes of inflow and increased water exchange rates were associated with increases in fish standing crop and changes in the size structure of fish communities in several of the reservoirs.

Angler Use and Harvest. — Estimates of angler use and harvest have been an integral part of the fishery studies on White River impoundments. Use and sport fish harvest have decreased markedly since impoundment. Data collected during the past 11 years have been integrated into a time series study that will ultimately permit prediction of use and harvest on the basis of environmental variables (e.g., temperature, conductance, transparency, water inflow, and surface area).

Analysis of data from a 3-year study of the Bull Shoals tailwater put-and-take rainbow trout fishery indicated an efficient harvest of trout (more than 90% of the fish stocked) during the years of low water release. During sustained periods of high tailwater flow, however, both effort and harvest dropped precipitously — though mean size of the trout caught increased substantially.

Multi-outlet Reservoir Studies in DeGray Lake.

— In limnological and population dynamics research on multi-outlet DeGray Lake, we continued to develop data bases on the fishery during a period when the water is being released from the epilimnion, for comparison with data for a future period when it will be released from the hypolimnion, and to provide data to the Corps of



Annual sport fish harvest, Beaver Lake, 1964-75, with plots of the 12-year mean of 21.3 pounds per acre, and predicted harvest (Formula E, National Reservoir Research Program formula compilation, June 1974. Mimeo, 11 pp.). Harvest estimates do not include night fishing.

Engineers, Waterways Experiment Station, for development of physical and mathematical models of DeGray Lake.

Largemouth bass population estimates in DeGray Lake were completed during the spring of 1976 to establish biomass level of the principal predator. The lakewide average of 459 bass/km of shoreline was 6 km less than the 1975 average. Age and size composition determined for 1,898 bass captured in 1975 indicated that 61% of the estimated number and 10% of the weight was composed of 1-year-old (1974 year class) bass less than 250 mm long. Bass of the 1966-68 year classes (hatched before impoundment) made up only 2.3% of the numbers and 12% of the weight.

Cove sampling with rotenone in August of each year since 1974 indicated that total fish biomass of DeGray Lake has decreased each year. Standing crop estimates (kg/ha) averaged 416 in 1974, 248 in 1975, and 186 in 1976. Although declines in the standing crop estimates were noted for most species in 1976, reduction in the biomass of adult gizzard shad accounted for much of the decrease. Biomass estimates for bluegills, crappies, and channel catfish declined in 1976, but the estimated mean crop of largemouth bass was 16.4 kg/ha in 1976 as compared with 13.1 kg/ha in 1975. Reproductive success of largemouth bass increased in 1976, with a lakewide average of 519 young-of-the-year per

hectare, compared with 304 in 1975.

Twelve biweekly collections of centrarchids were made beginning in April 1976 to define food habits for modeling purposes. Largemouth bass stomachs contained shad, centrarchids, steelcolor shiners, brook silversides, frogs, crayfish, and (in stomachs of the smaller bass) a few aquatic insects. Analyses of the stomach contents of other centrarchids are incomplete.

Mid-water trawling is being used to estimate population size and production of pelagic larval fish in DeGray Lake. The principal species are the threadfin shad, gizzard shad, black crappie, white crappie, and sunfishes (*Lepomis*). Bimonthly estimates were made from May through September 1975 and 1976. Catches of threadfin shad, the most abundant larval species, increased in 1976. Perhaps as a result of higher than normal spring water temperatures, peak catches occurred during the 3rd week in May 1976, 2 weeks earlier than in 1975. The 1975 threadfin production was about 7 kg/ha.

Larval fish loss in discharge from a power-generation plant was also studied. Because the bottom of the present outlet of DeGray Lake acts as a weir and coincides with the top of the thermocline at normal water levels, most of the water discharged comes from the epilimnion. During most years, high discharge volumes will coincide with peak larval fish abundance in the epilimnion during May and June. Weekly 1-m net samples were taken below the dam from April through August. Numbers of larval fish collected reached a peak of 0.79/m³ of discharge water in May 1975, and 1.42/m³ in May 1976. Total water volumes discharged during May and June were 220.4 million cubic meters in 1975 and 91.6 million cubic meters in 1976. Estimated larval losses during these 2 months were 153.2 million in 1975 and 72.1 million in 1976.

SOUTHEAST RESERVOIR INVESTIGATIONS

Effect of Thermal Discharges on Fish. — Addition of heated water to the environment from the increasing number of nuclear fuel and fossil fuel steam-electric plants has caused much concern among aquatic biologists. Water temperature regulates the rate of all life processes for fish and other cold-blooded aquatic life, and changes caused by power plant discharges can have both detrimental and beneficial effects. Recent trends in constructing pumped-storage hydroelectric power plants have placed additional unknown stresses on

aquatic communities. In pumped-storage projects, electricity is generated during hours of peak electrical need; during hours of reduced power needs, water is pumped back into the reservoir for reuse during the next period of peak power generation. Rapid water-level fluctuation, strong currents, and marked water temperature changes are usually associated with this operation. There now are about 22 pumped-storage plants in operation and over 1,000 potential pumped-storage sites have been identified in the United States.

Southeast Reservoir Investigations was established in 1972 to evaluate long-term effects of thermal discharges from steam electrical generating plants and pumped-storage hydroelectric plants on fish and other aquatic life in reservoirs. Research to date has been in Keowee (18,000 acres) and Jocassee (7,500 acres) reservoirs in northwestern South Carolina. Keowee Reservoir is the source of cooling water for Oconee Nuclear Station, and hydroelectric power is generated at Keowee Dam. Keowee is the lower reservoir and Jocassee the upper reservoir of a pumped-storage hydroelectric plant. Additional pumped-storage facilities are planned, in which Jocassee will be used as the lower reservoir.

Fish populations in Keowee and Jocassee reservoirs are sampled with trawls, seines, gill nets, electroshocker, and rotenone to measure changes in composition and abundance of fish species and to collect life history information. Plankton and bottom-dwelling animals are sampled seasonally by standard methods. Water-quality data are collected to describe environmental changes caused by power plant operations. Sampling methods and locations have been standardized so that results can be compared between areas each year. A creel census conducted in cooperation with the South Carolina Wildlife and Marine Resources Department documents angler use and harvest in the two reservoirs.

Data analyzed identify changes in aquatic life that occurred in response to changing environmental conditions while the reservoirs were filling; during the early years after the reservoirs filled, before power plant operations; and during the periods when the plants went into production. The three reactors at the Oconee Nuclear Station became fully operational in early 1975 and all four pump turbines at Jocassee Dam were operable in mid-1975. Data showing the long-term, possibly subtle, effects of these power plants are not yet available. However, some effects of these power plants are becoming obvious.

Since 1971 there have been significant changes in the water temperature of Keowee Reservoir. Average annual weighted (by volume) temperature at all stations was 12.9° C in 1971 and 17.6° C in 1975. Results from the first 8 months of 1976 closely parallel those for 1975, suggesting that the reservoir may be reaching the maximum temperature likely to occur under the current operating capacity of the nuclear power plant. The reservoir warms earlier than normal in the spring, resulting in earlier spawning of fish and earlier emergence of midge larvae.

Water temperatures at 15 m were closely correlated with percent operating capacity of the nuclear plant, whereas temperatures at 1 m were generally correlated with the weather. Since the plant has been in operation, the depth of the thermocline during summer has been progressively depressed. As a result, temperatures at 20 m during late summer have increased 13° C over pre-operational levels. From September to April, when the plant is operating at 80-90% of capacity, a thermal plume in which temperatures are 1°-5° C above natural temperatures extends from the surface to a depth of 16-18 m and covers about 20% of the reservoir.

Jocassee Reservoir also exhibited considerable temperature changes since all pumping units went into operation. The reversible turbines move warm water from Keowee Reservoir up 300 feet into Jocassee Reservoir. Influence of this added heat is of particular interest because a "two-story" trophy trout fishery was established in the reservoir by the South Carolina Wildlife and Marine Resources Department in late 1973. At this latitude trout in reservoirs are restricted to cool, well-oxygenated waters of the thermocline during summer. Adding heated water from Keowee has shifted the upper limits of the trout habitat downward in late summer. Since the water of Jocassee Reservoir usually does not mix completely in the fall, there is little or no oxygen at the greater depths, thus resulting in further reduction of trout habitat. There has been a net loss of about 25% in summer trout habitat since 1973.

Effects of habitat alterations on organisms near the bottom of the food chain are difficult to measure and evaluate, but the information is essential to understanding changes occurring throughout the aquatic community. Zooplankton densities decreased 43% between 1973-74 and 1974-75 and remained stable into 1975-76. These changing values are more closely related to the standing crop of threadfin shad (the major

planktivore) than to the level of power plant operation. A large decrease in planktonic larvae of phantom midges (*Chaoborus*) during this time also appears related to shad abundance.

Entrainment of zooplankton in the cooling water supply is limited to July, August, and September. Mortality from passage through the plant appears to be small. Maximum temperatures have not reached levels lethal to zooplankton.

Zooplankton species composition throughout the reservoir has remained stable, except for *Daphnia laevis*, which was common in 1973, absent in 1974 and 1975, and reappeared in 1976. Overall, the operation of Oconee Nuclear Station has had no marked effect on zooplankton to date. Likewise, the power plant appears to have had no major effect on the abundance and species composition of benthic organisms.

Changes in feeding, growth, and reproductive success of fishes usually occur after water temperature changes or other habitat modifications. Consequently the life histories of four major game fishes in Keowee Reservoir have been followed since the laboratory was established. Estimates based on scale samples indicate that growth rates of bluegills and yellow perch have remained nearly constant since 1972. However, growth of black crappies and largemouth bass appears to have increased. After plant operations began, the weights of adult bass were nearly double those of fish of the same age collected in earlier years.

Interpretation of the growth changes of black crappies and bass is difficult because the reservoir was stocked with threadfin shad as a prey species at about the same time the power plant began operation. Examination of bass stomachs indicated that bass fed heavily on threadfin shad during the summers of 1974 and 1975.

Stomachs from young-of-the-year black crappies (5 to 22 mm long) and yellow perch (6 to 30 mm long) contained only zooplankton before heated water was added to the reservoir. Zooplankton and immature aquatic insects made up most of the diet of adult black crappies (130 to 239 mm long) and zooplankton most of the diet of adult yellow perch (to 300 mm long). These early observations stress the need for understanding changes which occur at all levels of the food chain.

To determine time and success of spawning and develop estimates of relative abundance, growth rates, and mortality of young fish (4 to 30 mm long), we operated experimental fine-mesh trawls (one with 0.8-mm mesh openings and one with 2.5-mm mesh) from March through September in both

reservoirs. Trawl catches of yellow perch, black crappies, and sunfish were highest in 1973 and declined progressively through 1975 as heated water was added to Keowee Reservoir. All remained low in 1976 except for the black crappie, which returned to the 1974 catch level. Catches were lowest near the heated water discharge after the plant began operating. No trends or changes in abundance of larval fishes are now discernible in Jocassee Reservoir.

Threadfin shad were stocked by the State in 1973 in Jocassee Reservoir and in Keowee Reservoir in 1974 to provide additional food for predatory species. They have reproduced and now make up an important part of the trawl catches in both reservoirs.

Fish are sampled in coves (by application of rotenone) annually in both reservoirs to provide estimates of species and size composition of the nearshore fish population. In general, no major changes have occurred since the power plants began to operate. Reduction of larval yellow perch and sunfish, suggested by trawling, have not been detected in the cove samples. Data for crappies, however, correspond with those from the trawls: numbers were reduced in 1976 samples.

Recent samples show that Keowee Reservoir contains about 50 pounds of fish per acre and Jocassee Reservoir about 30 pounds. Largemouth bass contribute 4 pounds per acre to Keowee Reservoir and 6 pounds to Jocassee.

SOUTHEASTERN FISH CULTURAL LABORATORY

Striped Bass Nutrition. — We completed the final two of nine feeding trials begun in 1975 to define several nutritional requirements of striped bass fingerlings in intensive culture. Data were assembled, reduced, and analyzed statistically for information on optimal protein and lipid content in synthetic diets, feeding rates, and stocking rates in tank culture so that a more complete description of a least-cost diet can be used in ration formulations for production. The following protein (casein) contents should yield the following respective growth rates (g/day per fingerling): 32%, 0.184; 34%, 0.210; 36%, 0.234; 38%, 0.244; 43.5%, 0.247; and 49%, 0.250.

Feeding rates with optimal protein level (38% casein) may be selected in consideration of the following conversions: 1% (dry diet) of body weight per day yielded 0.126 g flesh per day per fish; 2% yielded 0.225 g; and 3%, 0.245 g. Conversion

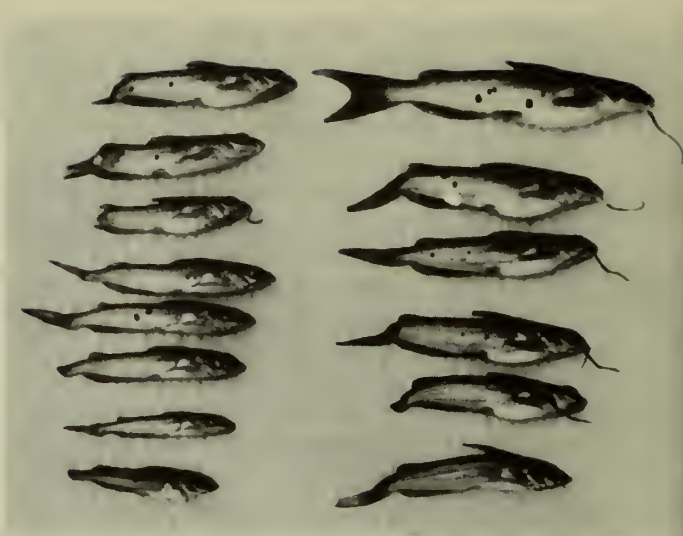
efficiency was 2.4, 2.9, and 3.8, respectively.

Data on lipid requirements are not complete but growth rates in short-term feeding trials were linearly proportional to lipid contents in diets containing 0-6% salmon oil (6% is the highest content tested thus far).

The difficult problem of developing acceptable larval foods is still given high priority. We tested several "whole" foods on hatchling striped bass, both with and without initial feeding of live brine shrimp nauplii or *Daphnia*, and with several methods of application. The foods were prepared from eggs, frozen brine shrimp, beef liver, canned mackerel, casein-base diet, or ground Ewos Trout Starter (after gelling with agar or gelatin, drying, and sizing to 50-100 μ m), along with commercial microencapsulated food. None of these feeds proved successful for production use, but the results gave us a better understanding and definition of problems with larval foods to help design future studies.

Largemouth Bass Nutrition. — We completed the final two of seven feeding trials begun in 1975 to define nutritional and related factors in tank culture of largemouth bass. Results of these tests provide guidelines for protein and lipid content in least-cost maintenance and production rations for fingerling bass. Protein content of 36% gave best growth (contents of 32 to 38% were tested). In earlier trials, protein up to 54.5% did not improve growth over that given by 38%. Diets containing 6% salmon oil (0 to 6% tested) gave best gains; 4.5% and less appeared to be limiting.

Channel Catfish Tail Abnormalities. — Abnormal tails that developed in up to 16% of the catfish fry in different lots range from complete club tail to partial tail development. A pilot survey of 17 lots of catfish fry with the same general history had ascorbate levels in eggs ranging from 4 to 20 μ g/g (fresh weight). A statistical correlation was not possible because too few samples were available to make a valid test, but the highest incidences of abnormal fry developed from eggs having less than 6 μ g ascorbate per gram (fresh weight) of eggs. A few brood stock fish with short, stubby tails also had eggs in which ascorbate values were low. Inasmuch as short-tail males crossed with normal females yielded normal fry, a "cytogenetic" effect is apparent. Too little information is as yet available to judge whether this condition resulted from a deficiency in vitamin C metabolism, a condition that might be caused by long-term exposure to organochlorine residues, inbreeding, or other factors.



Tail deformities occur in up to 16% of the channel catfish developed from eggs with low ascorbate levels (normal, upper right). The possible causes of this "cytogenetic" effect being investigated include diurnal low dissolved oxygen, poor water quality, temperature effects, and inadequacy of the brood stock — perhaps resulting from diet deficiency during egg development, from inbreeding, or from exposure to pesticides. Photo by B. F. Grant.

TUNISON LABORATORY OF FISH NUTRITION

The Energetic Efficiency of Fish. — Fish are more efficient in converting food energy into body growth than are other domestic animals. This fact was confirmed by experiments which directly measured the heat produced by living fish. Feed which is digested and absorbed either appears as growth of the animal or is used to supply energy and appears as heat. Measurement of the heat produced gives an indication of energetic efficiency.

It was found that fish are much more efficient in metabolizing protein than are other animals. Warm-blooded animals lose as much as 30% of the energy of protein as extra heat production after a high protein meal. This loss in rainbow trout was less than 10%; thus more of the energy in the feed was available for growth and less was used for heat production.

Brood Stock Nutrition. — Diets for brood stock cutthroat trout in hatcheries have been, at best, only moderately successful. Therefore, a cooperative pilot study was undertaken with the Fish Cultural Center in Montana to obtain basic chemical data on eggs from various hatchery and wild trout. The results obtained provide a sound basis for formulating diets better balanced in essential amino acids,

which are the vital components of protein.

Prevention of Cataracts Induced by Whitefish Meal. — Rainbow trout fed whitefish meal as a source of protein develop lens cataracts; however, cataract formation can be completely and economically prevented by dietary supplementation with a newly developed practical mixture of essential minerals that also improve growth and feed conversion.

Influence of Water Temperature and Ammonia on Ionic Regulation of Trout in Closed Systems. — Under conditions of complete water reuse, the toxicity to salmonids of nitrogenous metabolic wastes (ammonia, nitrate, and nitrite) in culture water has routinely been found to be less than that in either flow-through culture systems or reuse systems in which water is periodically replaced for waste flushing. Retaining 100% of the culture water in recirculation conserves essential nutrients for the organisms in the biofilter that purify the water through their metabolic activity; performance is further improved by adding nutrients (inorganic carbon and calcium) to the culture water for use by the filter organisms. It is believed that increased numbers and metabolism of the purifying bacteria in closed-circuit culture systems contribute toward reducing the toxic effects of nitrogenous wastes at the higher measured concentrations through sequestration in, or modification by, the retained biofilter organisms. A practical 100% water reuse system for salmonid culture can be significantly smaller than one which wastes filter organisms and nutrients with each discharge of culture water during a dilution cycle.

Stability and Efficiency of Vitamin C and Vitamin C-sulfate in Rainbow Trout Diets. — Chemical studies conducted to measure the stability of conventional vitamin C (C) in fish diets stored for 1 and 3 months at room temperature showed 70 and 98% decomposition. In contrast, results for vitamin C-sulfate (C-SO₄) stored for 3 months at room temperature and at 113° F showed losses of less than 20 and 30%, respectively.

Quantitative nutritional experiments showed that C-SO₄ was as effective as C, on a molecule-to-molecule basis, in preventing deficiencies in trout, and that the minimum dietary requirement was considerably lower than indicated in the literature.

Heat-treated Full-fat Soybeans for Rainbow Trout. — Satisfactory growth and health were obtained in trout fed heated full-fat soybeans in starter diets containing only 10% fish meal and in grower diets containing none. Growth of trout and level of an antinutritional factor correlated with the

degree of heat treatment of the soybeans.

Vitamin D Requirements of Fish. — Reports on the nutritional role of vitamin D vary because of differences in dietary ingredients, level of calcium, form of the vitamin studied, and species or age of fish. The requirement needs to be clarified. Two experiments with rainbow trout indicated smaller growth responses (ca. 10%) to supplements of vitamin D and calcium that were related to the type of diet. There appeared to be no vitamin X calcium synergism.

Feed Use as Affected by Growth Stimulants. — Several feed additives, some of which are used to promote growth in swine, poultry, and cattle were tested for their ability to stimulate trout growth. None of the compounds tested, however, improved growth rate. Five of the agents markedly depressed liver size (by 40%) and one — stilbestrol — retarded growth rate, increased liver size, caused liver degeneration, and decreased liver glycogen by 70%.

WESTERN FISH DISEASE LABORATORY

New Vaccine Delivery System. — In a continuing effort to improve protection of fish by immunization, the Western Fish Disease Laboratory, working cooperatively with Wildlife Vaccines, Inc., Denver, Colorado, has developed a method to immunize large numbers of fish in a safe, expeditious, effective, and economic manner. We found that fish would take up large quantities of vaccine if they were placed in a hyperosmotic solution for about 2 minutes and then transferred to the vaccine for about 3 minutes. Five variables were found to be important: antigenic mass, type and concentration of the hyperosmotic solution, pH, duration of exposure, and temperature.

The vaccine solution does not enter the fish through the mouth. Some vaccine enters through the gills, but the major portal of entry is the lateral line. The association of the lymphatic system with the lateral line may explain the effectiveness of this vaccination method. We have successfully immunized salmonids to enteric redmouth disease, *Vibrio anguillarum*, and infectious hematopoietic necrosis virus using this procedure. Although the method was developed primarily for the delivery of vaccines to fish, it perhaps could be used for administering chemotherapeutics, markers, essential nutrients, or other substances difficult to administer to large numbers of fish, especially when the oral route cannot be used.

Toxicity of Nitrate to Developing Trout Eggs. — Inasmuch as intensive agricultural practices are known to result in high nitrate levels in ground-water supplies used by hatcheries, we carried out a study to determine whether nitrate levels commonly found in some groundwater inhibits normal development and hatching of trout eggs. Groups of eyed rainbow trout eggs were exposed to levels up to 20 ppm nitrate for 2 weeks before and 4 weeks after hatching. The exposure of eggs and fry for this 6-week period caused statistically significant increases in egg mortality at 20 ppm and in the frequency of abnormalities in fry hatched from eggs exposed to concentrations of 5 ppm or higher. In addition, a subjective observation was that many of the fry being exposed to 20 ppm appeared lifeless and often were mistaken for mortalities until reflex movement was shown when the fish were disturbed.

Ozone Toxicity to Fish. — The toxicity of ozone to fish must be determined before recommendations can be made for the use of this chemical to disinfect water supplies or as a replacement biocide for chlorine. To obtain this information, we exposed juvenile rainbow trout (average weight, 15 g) to dissolved ozone up to 0.002 ppm in a continuous-flow system. Ozone was toxic to rainbow trout (estimated 96-hour LC₅₀, 0.004 ppm ozone). Subjectively, fish exposed to the two highest ozone concentrations showed increased respiration rate and “coughing” frequency, and the gills became pale. Loss of equilibrium often preceded death by several hours, as it commonly does when fish are exposed to toxicants. Fish exposed to ozone at the two highest levels suffered relatively severe blood chemistry disturbances, characterized by high blood sugar and abnormally low sodium and

chloride levels. Examination of circulatory blood smears stained with Leishman-Giemsa indicated significant decreases in lymphocytes and increases in neutrophils and immature erythrocytes, at all ozone levels. The Leishman-Giemsa stained kidney imprints showed no apparent morphological change. Histologically, the gill epithelium of some fish exhibited severe hyperplasia and some epithelial separation. Many of the hyperplastic areas were extensive enough to cause “clubbing” of the lamellae and the filaments.

Screening of Chemicals for Disease Treatment.

— There is a continuous need to identify chemicals that have potential value for treatment of fish diseases — especially virus diseases.

The virucidal properties of iodine, chlorine, formalin, thimerosal, malachite green, and acriflavine were tested against infectious pancreatic necrosis virus. Iodine and chlorine showed good activity, but efficacy depended on the concentration of virus, presence of organic matter (calf serum), and water pH. Water hardness (0-300 ppm as CaCO₃) did not affect virucidal activity. The addition of 0.5% calf serum significantly reduced iodine concentration and virucidal activity. However, the addition of only 0.07% serum greatly reduced the chlorine concentration and the virucidal contact time was extended to 30 minutes.

A 60-minute exposure of the virus to 0.2% formalin failed to inactivate all virus. Thimerosal at 0.2% in 10 minutes and malachite green at 5 mg/l for 60 minutes also failed. Acriflavine at 500 mg/l for 20 minutes failed to inactivate the virus, but at 0.5 mg/l in cell culture media it prevented the development of cytopathology.

Migratory Birds

MIGRATORY BIRD AND HABITAT RESEARCH LABORATORY

Satellite Imagery Predicts Productivity Among Arctic-nesting Geese. — Arctic breeding grounds of North America supply most of the geese available to hunters in Canada, the United States, and

Mexico. Brant and snow geese breed only in the Arctic, and large segments of Canada goose populations breed there. Successful reproduction of geese in this region is dependent upon timely disappearance of ice and snow. The nesting and brood-rearing periods are short, and the opportunity for renesting or even nesting at all is greatly

curtailed if conditions are not favorable. In fact, the productivity of arctic geese is highly variable because of annual changes in breeding habitat conditions. In one year, the birds may be quite successful; the next year may bring virtually complete failure. In the past, the likely reproductive success of the birds unfortunately could not be determined in time to set appropriate hunting regulations. The region occupied by the birds is so large and so remote that aerial and ground censuses are not economically feasible. Earth-orbiting satellites have provided a means of predicting probable annual productivity based on presence or absence of extensive snow cover during June, a key period in the breeding season.

Interpretations of satellite imagery in 1973, 1974, and 1975 agreed well with later information gathered from counts of young in goose flocks and from the measured ratio of young to adults in the harvest. During the first 2 years, breeding conditions were poor and reproduction was very low. In contrast, satellite imagery in 1975 revealed much better habitat conditions. Breeding success that year proved to be much higher. Satellite imagery is not infallible — for example, nest losses caused by sudden storm tides cannot be detected. Nevertheless, this space-age tool has proved to be a valuable means of measuring “boom” and “bust” years in time to make appropriate adjustments in hunting regulations in the management of this important resource. Development of this monitoring technique resulted from cooperative efforts of the Service’s Office of Migratory Bird Management, the Migratory Bird and Habitat Research Laboratory, and the Canadian Wildlife Service.

Research on Shore and Upland Game Birds Continues. — The accelerated Research Program for Migratory Shore and Upland Game Birds is to develop effective management plans for this highly important group of birds. Each year, \$175,000 is contracted to States and universities for much-needed research on a wide variety of birds, including mourning and white-winged doves, band-tailed pigeons, woodcock, snipe, and rails. Of 32 studies now in progress, 9 are being conducted by State Conservation Departments, 18 by universities, and 5 by Cooperative Wildlife Research Units (Louisiana, Missouri, Oklahoma, Pennsylvania, and Wisconsin).

The Colorado Division of Wildlife gathered new information on breeding cycles of band-tailed pigeons. These pigeons respond not only to photoperiodicity but also to other environmental cues, especially food availability. If food is scarce,

pigeons may wander until they find adequate provisions. On occasion, the birds will react to unusually good acorn crops and nest for a protracted period of time. An abundance of food may account for reports of fall and winter nesting.

A mourning dove study in Oklahoma indicated that biologists should be cautious in using primary feathers and their coverts to backdate and estimate dates of hatch. Indications of delayed molt were apparent in 26% of a sample of 76 young doves. The delayed molt was observed among birds trapped during the winter and probably was due to harsh weather and limited food.

In Pennsylvania, an informative study has provided insight into some of the details concerning fall migration of woodcock. Onset of migration of nine radio-marked birds occurred between November 30 and December 9, 1973, and between November 18 and 29 in 1974. Departures coincided with high-pressure centers approaching from the north and west or low-pressure centers retreating to the north and east. Eight of nine woodcock departed 2.5 or more hours after sunset and at least seven of the nine left before midnight. Two birds were tracked by aircraft 125 miles SSW of the study area during two nights. Air speed of the birds was 22 and 28 mph. The birds flew only at night and followed a river system extending south into Maryland and Virginia. Local birds were among the last to leave; most woodcock from more northerly regions had already migrated from the area. Temperatures at or near freezing, accompanied by favorable winds, appeared to stimulate migratory flights. Findings of a Virginia woodcock study suggest that woodcock may nest more frequently in southern States than had been believed. Research by the Virginia Game and Inland Fisheries Commission has revealed that male woodcock “peent” in the northeastern portion of the State from mid-February to mid-June, with a peak of calling activity in late February. Nests have been located throughout most of the State, with the exception of the region west of the Blue Ridge Mountains. Most nests were found in March and April; the peak of hatch probably occurs in early to mid-April. The extent of woodcock breeding in the South has become an important question in woodcock management, and much additional research is needed to determine methods of measuring the contribution of southern breeding habitat(s) to rangewide woodcock productivity.

Ingested Lead Shot High Among Sora Rails in Maryland. — The incidence and adverse effects of ingested lead shot are well known for most

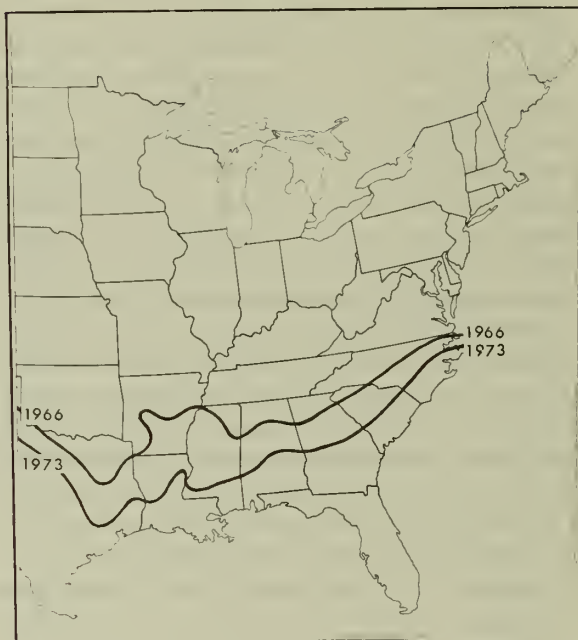
waterfowl. However, the magnitude of this problem for other groups of birds is not adequately understood. Sora rails are hunted in both inland and coastal marshes. A cooperative effort between the Migratory Bird and Habitat Research Laboratory and the Missouri Conservation Department documented the incidence of lead pellets in the gizzards of 934 soras shot in Maryland and Missouri. Ingested shot was found in 12.3% of the Maryland birds but in only 1.8% of the Missouri sample. Individual birds from Maryland marshes had ingested up to 28 pellets. None of the pellets was larger than No. 7½ shot. These findings suggest that lead poisoning may be an important cause of loss in sora rails, especially in Maryland.

Nesting Ospreys Counted in the Coastal Carolinas. — An aerial census, coupled with several intensive ground counts, was initiated in 1973 to determine distribution and abundance of ospreys. Counts were made in Chesapeake Bay in 1973 and were expanded in 1974 to include the coastal portions of North and South Carolina. An estimated $1,450 \pm 44$ pairs nested in Chesapeake Bay in 1973 and 571 ± 34 pairs were in the coastal Carolinas in 1974. Evidence from several small intensive study areas suggest little or no change in abundance during the past few decades. The high degree of successful nesting on a variety of man-made structures, such as navigational buoys in the Bay, together with heavy use of altered habitat in the Carolinas, indicates that the osprey is quite adaptable. The success of this initial research indicates that trends in osprey populations may be monitored accurately by using a twofold approach — aerial surveys to measure abundance, and ground studies to correct for birds unobserved from airplanes and to measure reproductive success. Results of the research suggest also that ospreys along the middle and south Atlantic coast are faring better than had been believed.

Breeding Bird Survey (BBS) Documents Range Expansions. — The BBS, a cooperative program sponsored jointly by the U.S. Fish and Wildlife Service and the Canadian Wildlife Service, is now in its 11th year of measuring changes in distribution and abundance of nesting birds in North America. Each summer, skilled bird watchers and their assistants, who help with the map reading, driving, and recording, arise 1 to 3 hours before sunup and drive to the starting points of some 1,800 randomly located survey routes. At exactly 30 minutes before sunrise each observer begins the first of 50 3-minute counts along a 24.5-mile transect. The resulting tallies are edited in the Migratory Bird and Habitat

Research Laboratory, then digested by computer to see which species are increasing and which are decreasing, and where these changes are occurring.

Few species are expanding their breeding ranges as dramatically as the barn swallow in North America. The 150-mile southward extension of range throughout the southeastern and south-central States that occurred between 1966 and 1973 appears to be continuing. Because it measures relative density of birds as well as their presence or absence, the BBS also shows that as the range has expanded, so have the areas of greater density. The Survey also indicates that other species are extending their ranges. Populations of the cattle egret, an invading species, are still increasing rapidly in the East.



Invasion of the southeastern States by nesting barn swallows. Breeding Bird Survey data show southern limits of breeding range in 1966 and in 1973.

NATIONAL FISH AND WILDLIFE HEALTH LABORATORY

Use of Laboratory Heavy During Its First Year of Existence. — From July 1, 1975, through September 15, 1976, a total of 1,219 birds, 16 mammals, 1 salamander, and 2 fish were submitted for necropsy to the Service's newly formed National Fish and Wildlife Health Laboratory. In addition, more than 2,000 bird necropsies were conducted in

the field by Laboratory personnel. Tissues from 577 other birds and 6 other mammals were also submitted to the Laboratory for testing, along with 21 bird eggs, 142 fecal samples, and 29 other samples. Birds examined varied in size from a hummingbird that died from aspergillosis to a sandhill crane that died from lead poisoning.

The most common findings were avian cholera, lead poisoning, avian botulism, salmonellosis, and aspergillosis. *Pasteurella multocida*, the causative agent of avian cholera, was isolated from 20 species of migratory birds and from all four flyways. Included were 10 species of ducks, 4 species of geese, whistling swan, eared grebe, California gull, little blue heron, sandhill crane, and snowy owl.

For the second consecutive spring, avian cholera erupted in the Rainwater Basin of south-central Nebraska. This important waterfowl staging area concentrates most of the midcontinent's population of white-fronted geese and is also frequently used as a stopping area by whooping cranes. During the avian cholera epizootic of 1975, approximately 35% of the loss of 15,000 to 20,000 waterfowl involved white-fronted geese. Nine whooping cranes had to be hazed from the area during the height of this outbreak to protect them from avian cholera. Approximately 10% of the 7,000 to 8,000 birds lost to avian cholera during the spring of 1976 were white-fronted geese. Other heavy losses of waterfowl from avian cholera occurred in California and South Dakota during that year.

Avian botulism was widespread, with the heaviest losses occurring in California, New Mexico, Illinois, Utah, and Minnesota. Other botulism die-offs, due to *Clostridium botulinum* type C, occurred in Montana, Texas, Oregon, Massachusetts, Wisconsin, North Dakota, Indiana, Maryland, Nevada, Virginia, North Carolina, Idaho, Washington, Colorado; also Ontario, Canada.

Losses from lead poisoning were also detected in all four flyways; the greatest number of losses involved snow geese from South Dakota, whistling swans in North Carolina, and a variety of ducks in Nebraska.

Erysipelas Kills Eared Grebes in Utah. — It was estimated that 5,000 migrating eared grebes, apparently caught in a heavy snowstorm on Great Salt Lake on November 26, 1975, died of what was diagnosed at the Bear River Research Station as erysipelas, probably aggravated by weather-induced stress. A few ducks and gulls were also affected, but an estimated 99% of the mortality was in the grebe population. The outbreak was



Pickup of dead snow geese during an avian cholera die-off in South Dakota. The bacteria (*Pasteurella multocida*) responsible for this disease survive for many weeks in the carcasses of dead birds. Scavenging by other birds, such as raptors, exposes them to the disease and further contaminates the areas where the carcasses lie, thereby increasing the exposure of waterfowl and other birds using the areas to the disease. Photo by M. Friend



Burning snow geese during an avian cholera die-off in South Dakota. Carcass weight of over 3 tons was disposed of by this means during the epizootic. Burning is the best way of destroying this contaminated material; rubber tires and diesel fuel were the principal fuels used. Photo by M. Friend

evidently acute, since no sick birds were seen before the storm, and the dead dotted the shoreline when the snow melted on November 29.

Erysipelas, best known in swine and turkeys, is caused by a bacterium, *Erysipelothrix rhusiopathiae*. It is transmissible to man, causing an infection, usually localized, called erysipeloid (unrelated to human erysipelas). The disease has been found in many species of wild birds and mammals, but mortality of comparable severity has never been reported.

Because of the potential health hazard to man and other vertebrate species, one or two bird carcasses were examined each week after the diagnosis was confirmed to ascertain how long E.

rhusiopathiae would remain viable in decomposing grebe tissues. The last isolation was made on June 3 — more than 6 months after the outbreak. Of possible epizootiological significance was the isolation of the bacterium from blowfly maggots from a decomposing grebe carcass.

Bacteriophages and Production of Botulinum Toxin. — In 1970, workers in Japan first reported that the capacity of at least some types and strains of *Clostridium botulinum* to produce toxin is dependent upon their being infected with specific viruses (bacteriophages). If the bacteria are relieved of their bacteriophages by treatment with chemicals or exposure to ultraviolet light, they remain biologically the same except that they no longer produce toxin.

C. botulinum is a hardy, spore-forming bacterium. Any treatment of a marsh drastic enough to destroy *C. botulinum* would probably also destroy the essential microorganisms and invertebrate life of the marsh. Studies are under way to determine the feasibility of attacking the bacterium by way of its bacteriophages on the assumption that they would be more susceptible to adverse chemical and physical agents.

The bacteriophages for study were separated from the bacterial cells by passing cultures through filter membranes that retain bacteria but permit passage of viruses.

Briefly summarized, the findings were: (1) Bacteriophages from a toxigenic strain of *C. Botulinum* did in some cases reinfect the same atoxigenic strain cured of its infection and thereby restored its toxigenicity; all atoxigenic strains could not be reinfectd. (2) Bacteriophages from one type-C strain did not necessarily reinfect atoxigenic cells of another strain. (3) Survival of bacteriophages was not affected by salinity (sodium chloride) in concentrations in the range of 0.1875 to 3%; in concentrations of 6, 12, and 24% they survived for 5 hours, but not for 24 hours. (4) Bacteriophages died in less than 1 hour at pH 4.0; from pH 5.0 to 8.0, they survived for at least 24 hours; and at pH 9.0 they were alive at 4 hours but not at 24 hours.

Lesser Scaups Killed by Coccidiosis During Spring Migration. — A die-off of 250 lesser scaups on the Bluestream Reservoir near Lincoln, Nebraska, during March 1976 was due to massive intestinal coccidial infections by *Eimeria aythya*. This is only the third known die-off due to this parasite. All have occurred in lesser scaups, during spring migration, and in the Midwest. The parasite has not been found in any other host.

Immunity to Botulism in Ducks Strengthened by Oral Administration of Toxin. — Studies reported earlier showed that groups of mallard ducks given repeated sublethal doses of *Clostridium botulinum* type-C toxin by the oral route were no more refractory to experimentally induced botulism than were untreated control groups, whereas similar birds given the same doses of toxin by the intramuscular route became solidly immune.

According to studies completed in 1975, however, some mallards with a basic immunity conferred by injections of toxoid (followed by active toxin) showed a marked serum antibody response to orally administered toxin if the dose was large enough. Others, even though their antibody levels increased only slightly, if at all, after oral challenge, appeared to be as resistant to intoxication as were those with high antibody titers. A few birds did not respond immunologically, showing no antibody increase and not enough protection to prevent death after three or more challenges. A possible reason an attack of botulism confers no immunity on wild birds is that a dose of toxin large enough to stimulate production of antibodies would ordinarily be lethal.

Large-scale immunization of wild birds is impracticable; but enough data are available to indicate that rare and endangered species, for example, subject to risk of botulism, once immunized by the injection of toxoid, may maintain their immunity by naturally acquired oral doses of toxin.

Captive Cranes Afflicted by Several Parasites and Bacterial Diseases. — Wildlife reared in captivity is subject to diseases that may nullify the intent of a rearing program. This is especially true when progeny of captive stock are to be released to supplement existing wild populations or to establish new breeding populations. Parasites and diseases acquired in captivity may also be released along with the wildlife, and therefore it is important to monitor the health of captive wildlife prior to release.

In one survey a collection of 92 cranes, representing 14 species, were tested. A blood protozoan parasite of the genus *Haemoproteus* was identified in an East African crowned crane and a hooded crane. *Salmonella typhimurium* was isolated from two East African crowned cranes and a Japanese crane, and *Salmonella kentucky* was isolated from a wattled crane. Of 79 fecal samples examined from these cranes, 32 contained the coccidian parasite *Eimeria reichenowi*, 36 had



Avioserpentiasis in a western grebe. The swelling above the superior mandible and the one below the inferior mandible result from the invasion of the connective tissue by female nematodes of the genus *Avioserpens*. Photo by J. T. Ratti.



Electrocution is a common cause of mortality among bald and golden eagles. The ruptured vesicles at the base of this golden eagle's talons are the result of electrocution from a high-tension line. Photo by E. A. Bell

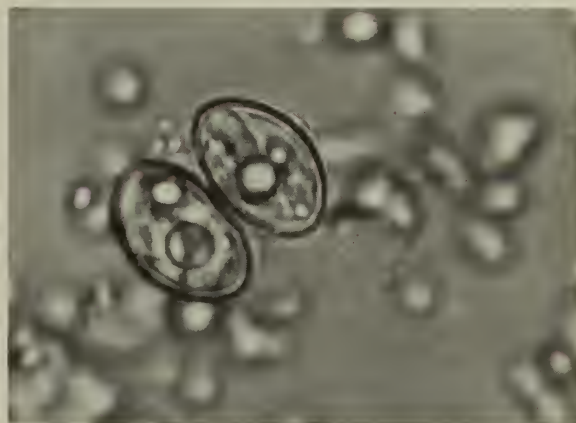
Eimeria gruis, 2 had *Capillaria* spp., 1 had eggs of another nematode, and 1 had fluke eggs. All tests for Newcastle Disease Virus and Influenza Virus were negative.

Since the survey, an East African crowned crane and a sarus crane have succumbed to a bacterial disease caused by *Erysipelothrix* spp. A Japanese crane severely affected with gapeworm (*Cyathostoma* spp.) was successfully treated with thiobendazol.

Nematode Infection in Western Grebes. — In July 1975, a western grebe with tumorlike swellings posterior to both the upper and lower mandibles and encircling both hock joints was submitted to the Bear River Research Station for diagnosis.

Microscopic examination of these turgid tissues disclosed that they were teeming with the mature and larval forms of the nematode *Avioserpens* sp. Two more grebes, with swellings posterior to the lower mandible only, were examined later in the summer, and milder infections with the same organism were observed.

This parasite has been reported in several species of birds, but never before in the western grebe. It may sometimes cause death by asphyxiation; in other cases the tumor is slowly resorbed and replaced by fibrous tissue.



Undescribed coccidian parasite from the intestine of a bald eagle. This parasite probably belongs to the genus *Isospora* and has been observed in several bald eagles necropsied at the National Fish and Wildlife Health Laboratory. Photo by E. A. Bell

NATIONAL FISH AND WILDLIFE LABORATORY

Status of Seabird Populations in the Gulf of Alaska. — A survey of nesting seabirds on Middleton Island in the Gulf of Alaska was

conducted for the second consecutive year. Sample plots were established for comparisons of breeding productivity in future years. Black-legged kittiwakes,

in contrast to most other colonial species around Alaska in 1976, experienced good breeding success; eggs were found at over 50% of the occupied sites. Production of young was estimated to be approximately one per active nest — nearly 23,000 for the entire colony. Pelagic cormorants also appeared to be successful, with nearly 1.7 eggs or young per nest halfway through the breeding season. A previously unknown colony of about 800 pairs of rhinoceros auklets was discovered in 1976.

An investigation of nest-site selection by kittiwakes revealed that although steeper cliff faces support the largest populations, more gradual slopes are preferred for nest placement within any given segment of cliff. Data are being analyzed for correlations of nesting phenology and productivity with the angle and height of the slopes on which nests are placed.

Status of Birds of the New York Bight. — A comprehensive report on the historical and present status of marine and coastal birds of Long Island and New Jersey was prepared for publication in the Atlas Monograph series of the Marine Ecosystems Analysis (MESA) Program. The manuscript discusses the status of important avian components of the Bight, with emphasis on population changes during the 20th century and the reasons for these changes. Other chapters deal with the effects of environmental contaminants on birds of the Bight, the problem of birds and aircraft, effects of habitat disturbance on bird populations, effects of hunting, birds as vectors of disease, and recreational benefits of birds. It was concluded that habitat modification and excessive hunting for commercial purposes have had the most significant detrimental effects on birds of the Bight but that the increasing background levels of environmental contaminants such as pesticides and oil are potentially serious threats.

Biology of Royal Terns. — The royal tern provides an example of a species that is potentially vulnerable to a variety of human influences. These birds nest in a relatively few large colonies on sandy barrier islands along the Atlantic and Gulf coasts. They are therefore susceptible to disruption by coastal land development, recreational use of beaches, and oil spills. Because the normal clutch consists of only one egg, reproductive potential is low.

Royal terns are normally 3 years old when they nest for the first time. Their age at first breeding is thus the same as that of several species of smaller terns, such as the common tern, and less than that of various gulls that are more similar to the royal

tern in size. Some royal terns return to breed at the same colony sites where they were hatched or where they nested in previous years; others nest in different colonies. In addition, locations of major colonies may shift from year to year. This ability to establish colonies in new locations is obviously a favorable adaptation in a changing environment.

The way in which human activities can both harm and benefit wildlife is well illustrated by this species. Some traditional nesting sites are no longer suitable because of heavy recreational use of beaches by swimmers, picnickers, and beach-buggy fans. On the other hand, channel dredging in adjacent shallow ocean inlets has created sandy islands that are free of mammalian predators and often relatively free of human disturbance. These islands are accepted by the birds and often provide better nesting habitat than natural beaches. Once grass and shrubs take hold, these spoil islands become unsuitable for terns but are attractive to nesting gulls and wading birds. Dredging of channels can be potentially useful as an intentional rather than a fortuitous means of creating habitat for royal terns and other colonial aquatic birds.

NORTHERN PRAIRIE WILDLIFE RESEARCH CENTER

Duck Nesting and Vegetation Quality. — An understanding of the nesting habitat requirements of certain duck species and other ground-nesting birds has been gained from measurements of vegetation in fields and at nest sites.

Visual obstruction readings were taken at 100 plots along linear transects in 7 quarter-section fields during the last half of May. These fields were searched for nests three times during the nesting season. Visual obstruction readings were taken at all nests located. The data from fields where vegetation was similar in height and density were lumped. Four fields totaling 496 acres had mean visual obstruction readings ranging from 0.6 to 0.8 dm, two fields of 249 acres had mean readings of 1.5 to 1.6 dm, and one field of 104 acres had a mean of 3.2 dm. Mallards, gadwalls, pintails, blue-winged teals, and northern shovelers all demonstrated apparent preference for fields with the tallest, most dense vegetation. Twenty-three dabbling duck nests per 100 acres were found in the cover with mean 100% visual obstruction of 0.6 to 0.8 dm, 39 nests per 100 acres in the 1.5- to 1.6-dm cover, and 63 per 100 acres in the 3.2-dm cover. An interesting finding is that upland sandpiper nests were not

found in the 3.2-dm cover and were most plentiful in the 1.5- to 1.6-dm cover, whereas American bitterns and deer fawns were found only in the 3.2-dm cover.

The range of 100% visual obstruction readings at nest sites of various species is important. Mallard nests were found at sites with mean readings of 1.25 to 6.25 dm (average 3.79); gadwall nests, 2.00 to 4.37 dm (average, 3.61); nests of pintails, 2.12 to 5.12 dm (average, 3.29); blue-winged teals, 0.25 to 6.25 dm (average, 2.04); northern shovelers, 1.62 to 3.20 dm (average 2.14); upland sandpipers, 0.25 to 2.00 dm (average, 1.09); and American bitterns, 4.12 to 8.75 dm (average, 6.05). It is obvious that habitat managed for various species of ducks will benefit a variety of other wildlife species.

Response of Nesting Ducks to Seeded Cover. —

The main objective of studies of duck nesting in fields of undisturbed grass-legume cover, conducted since 1968, was to obtain information on which to base management of upland nesting cover in the prairie pothole region. Studies on nine 30- to 130-acre fields of undisturbed smooth brome-grass-alfalfa cover in Edmunds County, South Dakota, during 1971, 1972, and 1973 indicated that this habitat type was productive of ducks. During the 3 years, 620 duck nests were studied: 38% blue-winged teal; 24% mallard; 24% gadwall. The average density was 31 nests per 100 acres, and the average rate of hatch was 56%.

Various mixtures of introduced cool-season grasses and legumes have been planted on cropland fields at the Center's Woodworth Station to test their value as nesting cover for ducks. Principal species of vegetation used for the planting trials were intermediate wheatgrass, tall wheatgrass, alfalfa, and sweet clover. On a per acre basis, production of ducks from planted cover 3 to 5 years old has generally been higher than that from other nesting habitats on the study area. An 82-acre cropland field planted to cover in 1972 proved to be a good nesting area in 1975. The cover mixture planted on the field was 5 pounds of intermediate wheatgrass, 3 pounds of tall wheatgrass, 2 pounds of alfalfa, and 2 pounds of yellow sweet clover per acre. By 1975, the fourth growing season after planting, the vegetation had developed into an excellent stand.

Three complete nest searches during the 1975 nesting season revealed 56 duck nests, 9 American bittern nests, 1 marsh hawk nest, and 1 ring-necked pheasant nest on the 82-acre plot. Hatch success of the duck nests was 48%. A variety of passerine birds also used the cover for nesting. Short-billed marsh



Mallard clutches are well protected from climatic extremes by the surrounding vegetation and the thick blanket of down and grass that the hens place around the eggs. Photo by J. T. Lokemoen.



A hatched mallard nest showing the diagnostic way the membranes and eggshell appear when the ducklings leave the egg. Photo by J. T. Lokemoen.



Although the upland sandpiper is a shorebird, it is seldom found near ponds but inhabits the prairie uplands and often perches on raised objects such as this fence post. Photo by J. T. Lokemoen.



Redhead ducks often lay eggs in nests of other waterfowl species. This picture shows a light-colored redhead duckling (foreground) that was hatched in a lesser scaup nest. Photo by J. T. Lokemoen.

wrens and common yellowthroats were very abundant. Other species that nested in lesser numbers were Savannah sparrows, red-winged blackbirds, and western meadowlarks. Use of the plot by nesting birds in 1975 represents a dramatic increase from the time it was idled from farming and planted with a grass-legume cover. In 1971, when the land was farmed, only one duck nest was found. The number then increased to 7 in 1972, 18 in 1973, and 25 in 1974.

Prairie Mallards Nest in Marshes. — Nest data gathered during the 1974-76 field seasons indicate that mallards regularly nest overwater in Class IV wetlands. This information is based upon nesting attempts made by radio-tagged and by unmarked hens on upland and wetland habitats of the study area. Seven of 14 nests initiated by seven radio-marked hens in 1974 and 1975 were in wetland habitat. Sixty-seven percent of the 46 active mallard nests located during the 1976 field season were overwater in 15 wetlands. Mallards generally selected nest sites in shallow water amid rank stands of old-growth cattails or hardstem bulrushes, or both. Other wetland habitats, although plentiful on the study area, were not used for nesting but were important in other aspects of their nesting and brood-rearing ecology. Overwater nest distribution on the study area reflects spacing of ponds supporting dense stands of cattails or bulrushes, or both. The highest density of nests overwater in emergent vegetation was seven on a 10.9-acre pond.

Mallard use of wetland habitat for nesting on a

regular basis is significant from both research and management viewpoints. The structure and form of overwater nests indicate considerable adaptation for nesting in wetland habitat, which suggests a long-standing association with it. Whether individual ducks readily shift between upland and wetland nesting habitats is not known. The limited data available lend some support to the hypothesis that relatively discrete subpopulations of upland and wetland nesters may exist in the region. Because of adverse pressures being exerted in upland habitats, the relative contribution by overwater nesters to annual production in the prairie pothole region may have risen markedly in recent years. In retrospect, the immediate and widespread use of nest baskets by mallard hens, when first introduced into North Dakota marshes a decade ago, presumably occurred because a sizable segment of the population was already adapted to nesting overwater and was seeking nest sites there. Baskets provide an acceptable alternative to natural vegetation for some of the overwater nesters, and high rates of reproductive success in these structures result in high homing rates, as documented in previous studies.

Foods of Prairie-dwelling Raccoons. — Few definitive studies on the raccoon have been conducted in the prairie pothole region, an area in which they have only recently become well established. This study was initiated to identify the feeding strategies of prairie-dwelling raccoons, including their relationship to nesting waterfowl in

the principal waterfowl production region of North America.

Radiotelemetry was used to study the nocturnal activities of a sample of individual raccoons throughout the avian nesting season. Detailed data relating animal activity to habitat type throughout specified time periods were accumulated. Simultaneous collection and analysis of raccoon fecal material yielded information on foods eaten.

In 1974, bird remains occurred in 27, 35, 37, and 17% of the raccoon fecal passages examined in April, May, June, and July, respectively. Field observations of telemetered raccoons indicated that a large percentage of the avian material was from carrion. In the same 4 months of 1975, avian eggs or embryos, or both, were found in 8, 26, 59, and 42% of the fecal passages examined. Also found consumed in increasingly greater frequencies throughout those 4 months were mollusks (3, 18, 53, and 58%, respectively) and insects (30, 35, 58, and 58%, respectively). Grain, a staple item, was found throughout the summer in 67 to 95% of the fecal passages examined during both years.

This study indicated that the raccoon most probably has a significant impact on the nesting success of some avian species in the prairie pothole region, though it appears less important as a predator on adult nesting birds. Waterfowl and other water birds are strongly indicated as the principal bird species affected.

Prairie Raccoons: Mobility and Habitat Use. — Raccoons have been considered one of the principal predators of duck nests in the prairie pothole region. In 1973, a 3-year study was initiated to determine movement and habitat use patterns of prairie raccoons and to relate them to potential depredations on waterfowl nests. Radiotelemetry was used to monitor raccoon activities during the waterfowl breeding season (April-July) on an intensively farmed region in eastern North Dakota. The 48-square-mile study area contained numerous large marshes, including several Waterfowl Production Areas.

Most individuals in the sparse (approximately two per square mile) raccoon population were equipped with radio transmitters. Movement patterns and home ranges varied with the sex, age, and reproductive status of the individual raccoon. Adult males moved regularly throughout home ranges that averaged 9.9 square miles, often covering the entire area in 2 or 3 nights. Relationships between individual raccoons and the absence of significant home range overlap suggested a form of territoriality among adult

males. A distinct dispersal characterized the movements of nonbreeding yearling males in May, June, and July. Unidirectional movements of 5 miles in 1 night were not uncommon during dispersal. Mean seasonal home ranges of yearling males averaged 4.4 square miles; home ranges before and after dispersal were similar in size. Parous or pregnant females, including six adults and one yearling, had home ranges averaging 3.1 square miles. Movements were confined to smaller (often less than 100 acres) home ranges around the litter site for 4-5 weeks after parturition. Nulliparous yearling females did not disperse and had home ranges averaging 2.5 square miles.

Although 82% of the nocturnal locations and 94% of the diurnal locations of the raccoons were in building sites, wooded areas, and wetlands, those three habitats made up only 10% of the study area. Use of wetlands increased concomitantly with decreased use of building sites throughout the April-July study period. Upland habitats such as pastures, hayfields, and dense, idle cover were seldom used by raccoons.

The varying movement patterns among the different sex-age groups suggest that the potential for nest depredation is also variable among groups. Nevertheless, the extremely large, well-patrolled ranges and the definitive patterns of habitat use of prairie raccoons suggest that a relatively small population has the potential for destroying many nests in widely separated islands of nesting cover.

Renesting Capabilities of Blue-winged Teal. — A study of the impact of changing limnological conditions on the renesting capabilities of known-age blue-winged teal was undertaken on 0.1-acre experimental ponds in light of four known factors: (1) Studies of the feeding ecology of breeding dabbling ducks on the North Dakota prairies have demonstrated that aquatic invertebrates dominate the diet of laying hens; (2) aquatic invertebrate populations inhabiting prairie wetlands are subject to extreme fluctuations in response to changing limnological conditions; (3) the impact of aquatic habitat on initial and renesting attempts of waterfowl is unknown; (4) aquatic invertebrates respond readily to habitat manipulation.

Yearling blue-winged teal females with easy access to an abundant invertebrate population were capable of producing four clutches of eggs. Two-year-old females that had fewer food resources subsequently reduced egg production below their level of performance as yearlings. Three-year-old blue-winged teal females were capable of producing five clutches of eggs when supplied a high protein



Although this blue-winged teal brood appeared to be feeding on duckweed, they were actually taking small snails, a favored food item. Photo by J. T. Lokemoen.

supplemental diet or a dense population of invertebrates. One hen laid 53 eggs, the weight of which exceeded her spring body weight by 3.8 times. Productivity, hatch success, and duckling survival up to 7 days of age were determined for hens held on different food regimes.

Tenth-acre experimental ponds were manipulated to produce an abundant invertebrate population capable of supporting a pair of blue-winged teal with sufficient protein to enable them to produce the maximum number of eggs. The same ponds, when manipulated to produce a minimal food supply, were incapable of providing sufficient food to maintain a pair of blue-winged teal.

Control birds fed a supplemental high protein diet increased their egg production from yearlings to 3-year-olds. Although egg production increased with time, laying characteristics associated with individual birds persisted. Females that were the most productive as 1-year-olds were also the most productive as 3-year-olds.

An assessment of ovary development in 77 wild birds examined from the immediate area, and the initiation of late clutches and broods found in the

wild, suggest that the phenology of nest initiations in pen studies is similar to that found in wild birds during years of abundant precipitation.

Postbreeding Activities of Mallards and Wood Ducks in North-central Minnesota. — Telemetry techniques were used to monitor the postbreeding activities of 129 mallards and 118 wood ducks on a 932-km² area of north-central Minnesota. Upon completion of breeding activities and before the flightless period, all mallard drakes departed the area; this exodus peaked during early June. Nesting success may have influenced the departure of postbreeding mallard hens. Of the broodless hens, 35% remained on the area, whereas half of the hens raising broods spent the flightless period on their breeding areas. An estimated 39% of the mallard hens on the area in the spring were present at the beginning of their flightless period. Tracking data and band recoveries indicated that most hens that moved out of the area probably remained within a 160-km radius and that some returned to the study area either before or during the fall migration. About 50% of the drake wood ducks and 40% of the hens left the breeding area before wing molt. The

timing of wood duck departures was similar to that of mallards. The flightless period of mallards and wood ducks began in mid-June for wood duck drakes and lasted into early October for some mallard hens. Late-molting mallard and wood duck hens all reared broods that same year. A minimum of 29% of the mallard hens on the study area in spring were still there at the beginning of the hunting season in early October. About 14% of the wood duck males and 43% of the females breeding locally remained on the area until early October. About 22% of the mallards and 16% of the wood ducks that reared broods were killed on the study area, compared with 9% of the broodless mallards and 5% of the broodless wood duck hens. Principal habitats used by postbreeding mallards were bays of large lakes with abundant emergent cover, particularly wild rice. Wood ducks tended to use similar habitat but also frequented small woodland ponds and flowages, especially after the flightless period.

PATUXENT WILDLIFE RESEARCH CENTER

Residential Development Affects Adjacent Urban "Natural Area." — In northern Baltimore, a very dense development — Cold Spring Town — is

being constructed immediately adjacent to an old, established natural area, Cylburn Park, providing the opportunity for a case history study. Systematic bird counts were made in four areas: in Cylburn Park, in a proposed buffer area between the Park and Cold Spring Town, in the area to be covered by Cold Spring Town, and in an old residential area adjacent to the new development. These data provide base-line information on the characteristics of the bird populations in the area before the development of Cold Spring Town is completed. They also provide information on the characteristics of bird populations associated with various habitats. For example, the densest breeding bird population occurred in the old residential area located just west of the Cold Spring Town construction site; the lowest density occurred in Cylburn Park, the established natural area. The residential area is a stable, middle-income community consisting primarily of detached homes at a density of about 10 dwelling units per acre. Over half the birds in this area were house sparrows, starlings, and pigeons, but the "native" bird population of mockingbirds, catbirds, robins, cardinals, and song sparrows was nevertheless higher than in undeveloped areas. The mature woods in Cylburn Park had the lowest density of birds but a good variety of species was present.

Mammals and Nonmigratory Birds

DENVER WILDLIFE RESEARCH CENTER

Abandoned Eastern Strip Mines Support Wildlife.

— Most surface coal mines worked before the passage of reclamation laws in the mid-1960's have developed productive wildlife habitat through natural succession. A cooperative study by personnel of the Denver Wildlife Research Center, the Virginia Cooperative Wildlife and Fishery Research Units, and Virginia Polytechnic Institute and State University has been undertaken to define the beneficial and adverse impacts on wildlife habitat for Virginia's 18,000 acres of abandoned mine lands and to determine the amount of

reclamation that is justified. Evaluation of wildlife use of 5-acre segments of 12 mined areas was completed, showing that approximately the same number of species of small mammals was found on 4 poorly vegetated, 4 medium vegetated, and 4 well-vegetated plots; however, the number of small mammals captured in 3 nights of kill trapping was related to the amount of vegetation, with 57, 81, and 99 being caught in the three types of habitat, respectively.

In contrast, a greater variety of songbirds was found in habitats with poor and medium vegetation than in well-vegetated habitat. Totals of 37, 40, and 32 species were found on three types of habitat

sampled. A detailed analysis of factors associated with the amount of vegetation indicated that soil potassium was most important. Failure to develop any vegetation at all was best explained by low pH. Nitrogen was not measured. Information gained from this study promises to be useful in an extensive reclamation project now under way in Virginia, Tennessee, Kentucky, and Alabama.

Golden Eagle Populations in the Western States.

— This study, designed to monitor changes in the population status of golden eagles, was started in Texas and New Mexico in 1964. In 1971 it was expanded to include important wintering areas in Colorado, Idaho, Utah, and Wyoming; in 1972, Montana was added; and in 1973, similar areas in Arizona, Nevada, Oregon, North Dakota, and South Dakota were included.



The cottontail rabbit is an important prey species for eagles and other raptors on the Montana-Wyoming coal-lease areas. Photo by D. E. Biggins.

During the wintering period of January-February 1976, flights over randomly located transects through study areas totaling 62,100 square miles in eight western States showed an average density of 11.0 golden eagles per 100 square miles (Arizona, Oregon, South Dakota, and Texas were not covered this year). Results of flights conducted over the same areas in 1973, 1974, and 1975 showed densities of 15.5, 12.2, and 10.5, respectively. Ranked in descending order, the

largest populations, as in previous years, were found in Wyoming, northwestern Colorado, and west-central Utah; lowest wintering numbers were in North Dakota. The greatest yearly fluctuations in eagle numbers occurred in northwestern Colorado, Idaho, Nevada, and Utah; populations in Montana and Wyoming remained relatively constant. The decline between 1973 and 1975 closely paralleled decreased nesting activity and productivity noted for golden eagles during the same years in companion nesting studies. A population "crash" of both jackrabbits and cottontails, the mainstays of the golden eagle's diet throughout much of the intermountain region during this period, is believed responsible. Future changes in golden eagle populations in winter will be monitored at 3-year intervals by flights over study areas.

Report on the Status of Peregrine Falcons in Baja California.

— The peregrine falcon has declined drastically throughout much of North America during the past several decades. Although the decline is attributed largely to the use of organochlorine pesticides (especially DDT), habitat destruction, shooting, disease, and other factors were also implicated.

Knowledge of the status of the peregrine in Baja California and other parts of Mexico is important because these southern populations could become a natural reservoir for repopulation by dispersion into the United States. Baja birds could also be a source of captive breeding stock for reintroduction into the United States. Peregrines have been reported to nest in good numbers in Baja, with over 50 known eyrie sites.

In 1976, a preliminary survey revealed a nearly complete absence of activity at 16 historic eyries along the Pacific Coast and in inland areas of the peninsula. Although time did not permit checking of 13 historic sites on Pacific islands, only 1 site is reported to have supported peregrines in recent years. Peregrines were sighted on 9 of 23 islands surveyed in the Gulf of California, and other observations reported them on 3 additional islands.

During the survey 27 peregrines were sighted — paired birds at 10 sites and 7 unpaired birds. Two active eyries were located. Two eggs were found at one eyrie site, and two newly fledged young and one addled egg were found at the other site. Food remains at the two eyries indicated that peregrines nesting in the Gulf of California prey upon a wide variety of avian species, including gulls, grebes, terns, murrelets, and warblers. Additional data on the status, food habits, eyrie characteristics,

pesticide residues in eggs, and prey species are needed for Baja California and interior Mexico.

Interior Least Terns Surveyed. — Least terns throughout the world are encountering difficulty due to changing or disappearing habitats, disturbance by humans, and other factors. Such problems have been well documented in recent years for our California least tern (now considered to be endangered) and the eastern subspecies, but no formal study has been made to determine the status of the subspecies that inhabits the Mississippi River and Great Plains. A low-level aerial survey of 2,000 miles of rivers during June 1975 showed that only 1,250 least terns nest in the vast area from New Mexico to Nebraska to Tennessee. Best estimates for each river system surveyed are as follows: Pecos, 50 birds; Brazos, none; Red, 25; Canadian, 25; Cimarron, 100; Arkansas, 50; Republican, none; Platte, 150; Niobrara, 150; Missouri, 100; Mississippi, 600; and Ohio, none. The construction of reservoirs and farm ponds in recent decades has reduced the frequency and severity of flooding, allowing the bare sandbars needed for nesting to become vegetated. Massive salt sources in portions of the Arkansas, Cimarron, Canadian, Red, Brazos, Colorado (Texas), and Pecos rivers largely prevent the water from being used for municipal, industrial, or irrigation purposes. Planned control measures will affect least terns directly by flooding four of the salt flats where they nest and indirectly by making the water so useful to humans that little will be left to support the small fish that the terns need for food. Additional improvements in navigation channels, planned for the Missouri and Mississippi rivers, may prevent the formation of enough sandbars. Periodic surveys are recommended to monitor changes in populations of least terns.

National Elk Refuge Research. — The objective of the National Elk Refuge located at Jackson, Wyoming, is to manage the area as elk winter range. This management program means that all forage grown on the refuge is left standing for the elk to take on a “free-ranging” basis. Better distribution of the elk over the available winter range will insure better utilization of the natural forage and reduce the need for supplemental feeding.

In the past, supplemental feed was in the form of baled hay. Research initiated in 1970 identified pelletized alfalfa as a good supplemental feed, and for the past two winters all of the elk (in excess of 7,500) have been fed alfalfa pellets during a portion of the winter (usually from mid-February through March). One man, using a 20-ton-capacity six-wheel-drive truck, has been able to feed 7,500 elk in

less than 5 hours each day. When baled hay was used, six men, working 8 hours per day, were required.

Current research has included studies to determine the minimum daily ration of alfalfa pellets. Baled hay was fed at the rate of 10 pounds of hay per elk per day. Alfalfa pellets have been fed at the rate of 8 pounds per elk per day. Research conducted during the winter of 1976 indicated that possibly 5 pounds per animal per day or less can be fed without detrimental effects on the elk or their reproductive success. The approximate 38% reduction in the amount of money spent for supplemental feed would be a significant saving.

Kenai Moose Research Center. — The Denver Wildlife Research Center, Kenai National Moose Range, and Alaska Department of Fish and Game are participating in a unique moose research project in the northern Kenai Lowlands of the Moose Range. Biologists from the Alaska Department of Fish and Game, who are responsible for moose biology research, are actively involved in studies of moose physiology, movements, and population dynamics. The U.S. Fish and Wildlife Service, responsible for moose habitat research, is investigating browse quality, production, and use in four 1-square-mile enclosures that make up the Kenai Moose Research Center.

In the Kenai area, paper birch is the most abundant browse plant and makes up the greatest proportion of forage in moose diets. The table below shows moose densities per square mile and percentage of birch plants browsed in the four enclosures and in outside stands over the 3-year period 1973-75. The percentage of plants browsed follows fairly closely the average overwinter densities of moose in each enclosure.

	1973		1974		1975	
	Moose population (per mi ²)	Browsed birch (%)	Moose population (per mi ²)	Browsed birch (%)	Moose population (per mi ²)	Browsed birch (%)
1			11	39.6	7	26.1
2	14	35.8	14	41.2	14	39.0
3	7	35.6	9	33.5	8	25.0
4	28	58.1	19	44.6	17	55.8
Outside				56.1		46.7

At first glance, it appears that up to 15 or so moose per square mile on a 7-month basis is not too high a density with respect to percentage of birch plants browsed, but two factors influence the overall effect on the supply of birch. One factor is the high snowshoe hare populations, so that the percentage of plants browsed by moose and by hares is considerably higher than that shown in the



Moose on the Kenai Peninsula have entered a period of decline as a result of successional changes in moose habitat, severe winters, hunting, and losses to predators. Current research is designed to determine wolf density, predation patterns, and the effects of predation on moose populations. *Photo by R. O. Peterson.*

table. The second is that 40% of the birch plants are under 1 m tall and only 20% of the birches eaten by moose are in that category. Therefore, the percentage of birches over 1 m tall that are browsed by moose is greater than what is shown in the table. A close examination of the response in annual production of birch to browsing will be required to understand fully the influence on birch populations at these various levels of use.

Though the moose populations in the enclosures appear to be extremely high, populations adjacent to the Moose Research Center are also high during the winter. This adjacent area is part of the 1947 burn and is known to support large moose populations. Winter censuses have documented 8 to 37 moose per square mile in the area, which probably explains the high use of birch stands outside the Center.

Browse Manipulation on Kenai National Moose Range. — In 1974, the Denver Wildlife Research Center and the Kenai National Moose Range initiated a research program to study the effects of prescribed burning and of crushing trees and shrubs by LeTourneau Tree Crushers on a 27-year-old burn on the Moose Range. Three areas were selected for the study; crushing of woody growth was scheduled for one, vegetation on another was to be burned, and an adjacent area was the control. During the winter of 1974-75, woody plants on about 1,500 acres were crushed. The prescribed burn has not yet occurred because of unsatisfactory weather or fuel conditions. Where about 35% of the

forest was not burned in 1947 and remains as islands of cover surrounded by stands of spruce and paper birch regrowth, paper birch is the dominant forage species for moose. Willow and aspen are consistently overbrowsed so that they are in decadent condition and produce little annual growth. From the present study we hope to determine which method of disturbance results in the fastest production of browse and which habitat types respond best to planned disturbance.

Crushing was effective from two standpoints. Density of competing spruce saplings was reduced in the regrowth stands by 68-81%. This reduction frees light, water, and nutrients for browse species and may be the most important effect of the crushing. Browse density has increased. In what used to be mature stands of spruce, aspen, or birch, density of aspen has increased in some cases from 0.3 plant per 5 m² before crushing to 7.7 plants per 5 m² after crushing. Birch has responded almost as well, and willow is now growing in some of those stands where it was absent before. In what used to be regrowth stands, the changes have not been as dramatic. Birch is now reaching precrushing densities of 2-10 plants per 5 m², and aspen and willow in some stands are denser now than prior to crushing.

Although increased density is a desired result of both disturbance techniques, we also hope to obtain a good mixture of the three browse species



Moose calf survival on the Kenai National Moose Range has been low in recent years. Causes of early mortality of calves and the influence of predation on calf survival are under investigation. *Photo by R. O. Peterson.*

Average number of selected bird species on three study plots of an Apache-Sitgreaves National Forest study area (1973-74 pretreatment, 1975-76 posttreatment).

Bird species	A (snag removal)			B (snag retention)			C (control)		
	1973-74	1975-76	% change	1973-74	1975-76	% change	1973-74	1975-76	% change
Flicker	4.5	2.5	-44	4.0	4.5	+13	4.5	5.5	+22
Gray-headed junco	8.5	21.0	+147	8.5	21.5	+153	5.5	14.0	+155
Mountain chickadee	4.5	4.0	-11	4.5	2.5	-44	6.0	3.5	-42
Pigmy nuthatch	15.0	7.0	-53	14.0	17.0	+21	10.5	16.5	+57
Robin	4.0	6.5	+63	7.0	18.5	+164	3.0	3.5	+17
Steller's jay	5.0	3.5	-30	4.0	6.5	+63	4.0	6.0	+50
Violet-green swallow	19.0	2.0	-89	16.0	29.0	+81	11.5	19.0	+65
Warbling vireo	7.0	3.0	-57	3.0	2.5	-17	4.0	1.5	-63
White-breasted nuthatch	3.0	1.0	-67	3.0	0.0	-100	4.0	3.0	-25
Williamson's sapsucker	4.0	2.0	-50	2.0	2.0	0	4.0	3.0	-25
Yellow-rumped warbler	29.0	21.0	-28	14.5	15.5	+7	16.0	16.5	+3
Total (all birds)	125	94	-25	106	147	+39	88	118	+34
Total (cavity nesters)	60.0	31.5	-48	53	75	+42	44	65	+48
Total (other birds)	65.0	62.5	-4	53	72	+36	44	53	+20

and to improve plant vigor through decreased competition from spruce and reduced browsing (for a few years) by moose.

Cavity-nesting Birds Respond to Snag Removal. — Dead trees, commonly referred to as “snags,” occur naturally in forests as a result of lightning, fire, disease, insects, parasites, and other causes. Many wildlife species use snags for nesting, roosting, lookout perches, food storage, and feeding. Snags are a necessary component of the forest ecosystem to some beneficial cavity-nesting birds.

Results of a study in the ponderosa pine type on the Apache-Sitgreaves National Forest in Arizona indicated that removal of ponderosa pine snags can be detrimental to some species of cavity-nesting birds. The study area consisted of three plots. Trees were harvested from two of the plots (A and B) within a timber harvest unit while the third (C) served as a control. Conifer snags were removed from Plot A and an effort was made to retain all snags in Plot B. Fourteen aspen snags remained on Plot A after the timber harvest, which provided nest sites for some birds. The greatest decline from preharvest numbers occurred in violet-green swallows and pigmy nuthatches, which nested mostly in ponderosa pine snags. Cavity-nesting birds declined by 48% in Plot A, whereas both the snag retention area (Plot B) and the control (Plot C) had increases of 42 and 48%, respectively. Birds that normally used either dead or live aspen for nest sites (mountain chickadees, flickers, and hairy woodpeckers) showed little response to the removal

of ponderosa pine snags.

Although birds nested in both dead and living aspen trees, only the dead portions of live ponderosas were used. Of the 93 cavity nests found on the study area, 66% were in ponderosa pine snags and 11% were in dead portions of living ponderosa pine. A preference was shown for snags over 19 inches dbh and for snags that retained over 40% of the bark. Snags 15 to 75 feet tall received nearly equal use as nest sites, but a significantly higher use was made of snags over 75 feet tall.

Clear-cut Burns Change Small Mammal Populations in the Northern Rockies. — In the northern Rocky Mountains, fire is applied annually to 30,000 acres of national forest to reduce logging slash and provide bare soil seedbed necessary for successful establishment of many species of conifers. Animal response to this practice is not only important as basic ecological knowledge but is also necessary for understanding the effects of rodents on establishment and survival of tree seed. Populations of small mammals are currently being studied in Montana's Flathead and Lolo National Forests to determine patterns of animal succession on experimentally burned areas, as part of a U.S. Forest Service study of fire as a forest management tool.

Small mammal populations were sampled annually in fall before and after logging and burning in two similar stands of mature larch, spruce, and Douglas-fir, 120 miles apart. Results from the two sites point to similar population trends during eight postfire years (1968-75) of snap-



General view of clear-cut in Douglas-fir, western larch, and lodgepole pine after slash burn, Flathead National Forest, Montana. Photo by C. H. Halvorson.

trapping one area, and six postfire years (1970-75) of livetrapping the other. Redback voles were most common (3 to 13 per 100 trap nights) in unlogged stands, followed by chipmunks (3 to 6 per 100 trap nights); deer mice were scarce (0.7 per 100 trap nights) in these stands.

Rodent abundance the 1st year after fire was low except for deer mice. Deer mice increased even in the burn year and remained the most abundant species on all disturbed areas (5-13 per acre). By the second postfire year, burn populations were higher than those in timber. In general, the most severely burned site — a hard-burned south slope — initially showed a greater number of animals than other burns, but only one species (the deer mouse) was

present. A very light burn had the fewest animals for 2 years — only four species (deer mice, chipmunks, long-tailed voles, and shrews). By the fourth postfire year (1974), the populations of the lightly burned plot had surpassed those of the severe burn and continued to increase; an average of 16 rodents per acre occurred in 1974 and 1975. Redback voles did not survive on either burn except at forest edges, whereas chipmunks were scarce at first but showed a gradual increase with developing plant cover.

When two clear-cuts were left unburned, rodent numbers were still very low after 6 years; however, by the 8th year, the largest variety and numbers of small mammals on snap-trapped plots (22 per 100

trap nights) occurred on these slash areas. Deer mice, long-tailed voles, heather voles, shrews, chipmunks, and redback voles were caught there. Unburned and poorly burned slash are persistent fuel and silvicultural problems in the region and appear to provide excellent rodent habitat as time passes. A wildfire area where dead trees were left standing was intermediate in rodent numbers (15 rodents per 100 trap nights) between unburned slash and clear-cut burns. Deer mice again were most common. Wildfire plots had best germination and survival of conifer seedlings among all habitats.

The important knowledge gained from these long-term studies shows that the deer mouse, an important consumer of tree seeds, thrives in several types of purposely and accidentally disturbed forest habitat. Rodent populations may be more abundant and diverse over a longer time span on areas with poorly burned or unburned slash than on hard burns. Further study will determine the point at which rodent numbers and species composition become similar to those in uncut forests. Results will also be correlated with plant succession and tree establishment in this cooperative research program.

Brewer's Sparrow Most Abundant User of Sagebrush Rangeland in South-central Wyoming.

— Land management agencies, industrial users, and private landowners have converted thousands of acres of big sagebrush rangelands to croplands, grasslands, and mine spoils through the years, by chemical and mechanical means. The potential influence of continuing modification of the sagebrush habitat on native animal populations is a matter of concern to those interested in the welfare of wildlife.

In 1968, a cooperative study was started with the U.S. Bureau of Land Management and the U.S. Forest Service in south-central Wyoming to determine the effects of the conversion of a stand of big sagebrush to herbaceous vegetation with 2, 4-D herbicide. Research emphasis was placed on soil water, streamflows, forage production, vertebrate animal populations, aquatic insect populations, algae, and terrestrial insect populations. Measurements of water yields, forage, and animal populations on two sagebrush drainages were started in 1969 and were continued through 1975. Herbicide treatment to kill sagebrush on one of the two drainages was completed in May of 1976.

Bird populations were inventoried annually from 1971 to 1975 on each of the two drainages. Plots were visited three or six times each during June, and cluster sightings or singing points of each species



The Brewer's sparrow is the most abundant of the four species of birds commonly nesting in dryland sagebrush, south-central Wyoming. Photo by M. H. Schroeder.

were assumed to indicate the number of breeding territories for that species on square 40-acre plots.

During the pretreatment period, 36 bird species used the sagebrush habitat and the small stream and meadow bottoms within it. Four species (Brewer's sparrow, vesper sparrow, sage thrasher, and the green-tailed towhee) consistently nested in the dryland sagebrush. The Brewer's sparrow, with an estimated average annual population of 72 birds per 100 acres, was the most abundant species on the untreated rangeland. It was dependent on sagebrush plants for its nest site and brood-rearing activities. The ground-nesting vesper sparrow was second in abundance, with an estimated average annual population of 40 birds per 100 acres. Sage thrashers and green-tailed towhees, both brush-nesting species, averaged an estimated 10 birds per 100 acres.

All available evidence indicates that the presence of living sagebrush cover is critically important to the maintenance of a Brewer's sparrow population. Sagebrush provides both structural support and protective cover to the bird's nest and young. After brush has been killed by treatment with herbicides, there is little likelihood that the remaining skeletal brush stems will provide suitable cover for nest site selection by this species.

NATIONAL FISH AND WILDLIFE LABORATORY

Biological Survey of the Tres Marias Islands, Mexico. — A joint team of biologists from the Direccion General de la Fauna Silvestre of Mexico

and the Laboratory visited the Tres Marias Islands during March 1976. The only previous extensive work on the Islands was by a U.S. Bureau of Biological Survey team headed by E. W. Nelson and E. A. Goldman in 1897. The recent expedition revealed changes that have occurred in the flora and fauna of the Islands during the past 80 years.

Greatest changes were noted for the largest island, Maria Madre, where the Government of Mexico has maintained a penal colony for many years. Extensive logging and clearing of forest for agriculture have changed the landscape considerably. A small frog appears to have been extirpated, possibly due to habitat changes near freshwater sources where it once occurred. An edible turtle no longer occurs on the island, and a large iguanid lizard has been reduced in numbers, apparently by human consumption.

In 1897, the most common small mammal in the Islands was an endemic subspecies of deer mouse (*Peromyscus boylii madrensis*). In that year, the black rat (*Rattus rattus*) was found only in association with the few houses on Maria Madre. Now, the black rat is the most common small mammal and is found throughout Maria Madre and Maria Magdalena. The deer mouse is scarce on Maria Madre at present, and despite extensive trapping, none were found on Maria Magdalena. However, they are still common on Maria Cleofas and San Juanito, where black rats are absent. Furthermore, an endemic rice rat, known only from a single locality on Maria Madre, is no longer found there, and black rats are abundant at that locality.

Status of the Mexican Freetail Bat. — Recent observations indicate that drastic declines have occurred in populations of the Mexican freetail bat (*Tadarida brasiliensis*). The size of the summer population at Carlsbad Caverns, New Mexico, declined from an estimated 8.7 million in 1936 to 200,000 in 1973, and the population at Eagle Creek Cave, Arizona, dropped from about 25 million in 1964 to 600,000 in 1970. Concern about the decline prompted the National Park Service to contract with the Laboratory for a 4-year study (June 1973–June 1977) to determine the factors causing the decrease in populations of this bat. Although the major portion of our data was collected at the maternity colony located in Carlsbad Caverns, our study included colonies in Arizona, Texas, California, and Mexico.

By use of high-speed motion pictures and still photographs, a useful and accurate technique was developed for estimating the size of populations of this bat. This technique was used for the first time

on September 1, 1973, at Carlsbad Caverns. The total number of bats that left the cave that evening was calculated to be 218,153. This photographic technique was used during the remainder of the study.

The ontogeny of fat deposition and depletion in the freetail bat was investigated. Organochlorine pesticides are stored in body fat, and this may provide a mechanism for preventing toxic effects. Therefore, in order to understand the potential effects of pesticides on bats, it is important to know the body fat cycles of the young in terms of both deposition and depletion. This study showed that body fat in bats from Carlsbad Caverns increases steadily from birth until the young begin to fly, then fat reserves are gradually used until fall migration.

The amount of pesticide stored in body fat was greatest in flying young from the Carlsbad Caverns. Flying young from Eagle Creek Cave, Arizona, Bracken Cave, Texas, and Newman Bridge, California, had similar chemical body burdens. As flying young from migratory populations mature at their maternity roosts, they grow, utilize body fat, and excrete body pesticides, whereas flying young from nonmigratory populations deposit fat and accumulate pesticides as they grow.

The hypothesis that the critical stage in the life cycle of the Mexican freetail bat may occur during the initial migratory flight was tested. The initial flight is the time when rapid mobilization of fat releases toxic residues that may reach the brain in lethal or detrimental amounts. By simulating in the Laboratory the fat mobilization that occurs during migratory flight, it was demonstrated that significant increases in organochlorine residues can occur in the brain and cause symptoms of poisoning in young bats.

Status of the Indiana Bat. — Contract research on the Indiana bat (*Myotis sodalis*) was completed during 1976. This work consisted of a study of the summer habitat and ecology of this endangered bat, a winter census of the species, and associated investigations. The number of living Indiana bats has declined 34% in the last 15 years. Declines in the two major breeding populations have been 73% in Kentucky and 8% in Missouri. Winter habitat consists of caves and mines, with suitable sites restricted to those that have cool and stable temperatures all winter long. These roosts typically have microtemperatures of 4° to 8°C, enabling the bats to maintain such a low metabolism that their fat will last until spring. Causes of the decline are natural catastrophes (flooding and freezing in caves), disturbance by biologists and caving

enthusiasts, and destruction of winter and summer habitat. Loss of 60,000 bats at one cave is attributable mainly to human disturbance. About half of the total decline resulted from habitat losses when structures were built at cave entrances. These structures interfere with cave thermodynamic processes and make roosts too warm for bat survival. These habitats can be restored, and the decline may be reversed.

Rates of survival of Indiana bats were calculated from recaptures of bats marked in cohorts of unknown age. Survival rates are high for 10 years after marking in females and 6 years in males. Both sexes can live as long as 13.5 years.

Adulthood is characterized by two survival phases. The first is a high and apparently constant rate from 1 to 6 years after marking. Annual rates of survival in this phase are 75.9% for females and 69.9% for males. The second is a lower and again constant rate after 6 years, with annual rates of 66.0% for females up to 10 years and 36.3% for males.

That some differential survival occurs between the sexes indicates distinct life histories with different patterns of mortality. For example, adult

males do not occupy nursery roosts. They also remain active later in autumn than females because many of them stay outside the caves to breed whereas females enter hibernation soon after they arrive in migration.

High survival under normal circumstances shows that the species' endangerment cannot be attributed to intrinsically poor performance in normal environments. Instead, the failure of the Indiana bat is intolerance of environments degraded by man.

During summer, Indiana bats live in small colonies consisting of adult females and their young. These nursery populations occupy hollows and cracks under bark of dead trees. Feeding habitat is restricted to air space near the leaves of creekside and floodplain trees. On a one-for-one basis, the loss of one summer colony is less detrimental to the species than loss of one winter colony, because a typical winter colony contains many more animals. However, land clearing by private landowners and land-use changes made by numerous State and Federal agencies are causing serious losses of summer habitat.

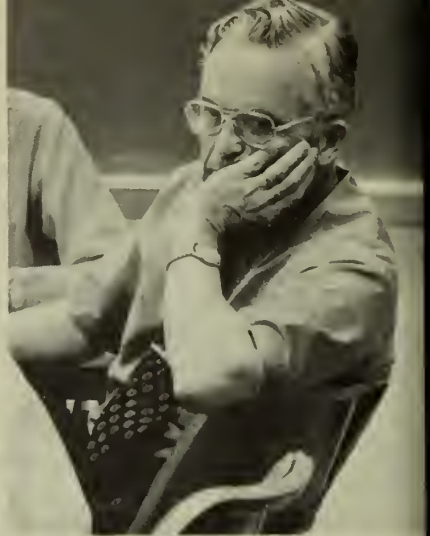
Cooperative Research Unit Program

COOPERATIVE RESEARCH UNIT PROGRAM

The Cooperative Research Unit Program is supported by the U.S. Fish and Wildlife Service and by the game and fish agency and land grant university in the State where each Unit is located. The Wildlife Management Institute is an additional cooperator for Wildlife Units. The Program began with the activation of the Iowa Cooperative Wildlife Research Unit in September 1935. The first Fishery Unit was activated in 1962 at Utah State University. Twenty-five Fishery Units have been in operation since 1971 and 20 Wildlife Units since 1972. In 1973 the two Unit programs were merged into one, administered by the Division of Cooperative Research.

The objectives of the Cooperative Research Units, in order of priority, are fish and wildlife

research, training at the graduate level, and extension service. Unit direction is provided by a Coordinating Committee composed of representatives from each cooperating agency. The Committee provides counsel and plans the long-term program to serve the mutual needs of the cooperators. Day-to-day operation is the responsibility of the Unit Leaders and the Assistant Unit Leaders, who are employees of the U.S. Fish and Wildlife Service. The Units are headquartered on the campuses of the cooperating universities, which provide expertise in related scientific fields; office, laboratory, and storage space; secretarial service; and utilities. All cooperators contribute funds and equipment to the Units, and additional research funds are obtained from various sources as grants and contracts. The Leaders and Assistant Leaders are granted full faculty status by the cooperating



universities and thus they are qualified to advise and direct graduate students and to teach formal courses. In the field of extension service, Unit personnel organize and participate in workshops and training meetings and provide technical fish and wildlife expertise as needed. Each year, Unit personnel publish many technical and general papers on fish, wildlife, and related subjects.

During the fiscal year 1975-76 (15 months in length due to the change in Federal fiscal years), personnel of the Fishery Units conducted 352 research studies, 129 of which were completed. Ninety-seven of the 323 studies carried out by personnel of the Wildlife Units were completed. These studies and other activities resulted in 116 technical and general publications from the Fishery Units and 127 from the Wildlife Units. Papers presented at meetings totaled 77 for the Fishery Units and 62 for the Wildlife Units. The following table summarizes training activities at the 45 Units during 1975-76:

	Fishery		Wildlife	
	M.S.	Ph.D.	M.S.	Ph.D.
Students in program	279	61	293	58
Degrees granted	92	15	84	15
Employment ¹				
Fish and wildlife biology	85	17	51	16
Other biology	1		2	
Education continued	16		26	
Peace Corps	2		1	
Miscellaneous and unemployed	7	3	13	

¹Includes students who accepted employment before completing all degree requirements.

COOPERATIVE FISHERY RESEARCH UNITS

Alabama. — Pond culture of many species is hindered by early maturity and frequent spawning that result in overpopulation and stunted growth. One way to control excessive reproduction is to develop monosex fish by chemically induced sex reversal. We have repeatedly produced all-male populations of tilapia with androgen-treated food. Present efforts are directed toward production of monosex female populations to be used in breeding studies.

Three naturally occurring estrogens (estriol, estrone, and 17 B-estradiol) were fed to 8- to 11-mm fry at 30, 60, and 120 µg/g diet for 3 or 5 weeks. Tilapia grown to maturity in ponds were harvested

and sexed. External appearance of the sexually dimorphic urogenital papillae was compared with the condition of the gonads as determined by dissection.

Estrogen treatment neither affected survival nor altered growth of experimental fry. Gonadal examination revealed no deviation from the expected 1:1 sex ratio, but significantly greater numbers of individuals in all treatment groups had female-like papillae. A greater proportion of atypical males occurred at the higher levels of estrogen dosage and in the longer treatment period. No atypical males were in the control groups.

Additional testing is in progress with more potent estrogens and with increased duration of treatments. Estrogen-induced sex reversal of homogametic males to functional females will permit breeding to yield all-male progeny. Chemical treatment would be necessary only to replenish brood fish.

Arizona. — The diel feeding of brook trout was observed in relation to invertebrate stream drift and benthos during seven 24-hour sampling periods, May to September 1975, in the East Fork of the Little Colorado River in the White Mountains of Arizona.

A diel difference was found in the feeding of brook trout. During the day trout fed efficiently on available foods, but at night their feeding efficiency decreased. The result was a high rate of consumption of invertebrates active during the day and a low rate for those active at night. Trout were nonselective in their use of drifting invertebrates.

Different factors controlled the availability of aquatic and terrestrial invertebrates to trout. This finding has significant implications for trout stream management. It appears difficult to increase significantly the availability of aquatic invertebrates, but the availability of terrestrial invertebrates depends largely on their abundance near trout streams. Poor land-management practices along streams could adversely affect terrestrial insect populations, on which brook trout rely for a large percentage of their food.

California. — Our research activities concerned primarily the ecology of northern coastal streams and reservoirs, and estuarine and coastal marine biology. Northern California streams are located largely in redwood forests, and the watersheds are now undergoing all stages of logging; all streams

are important salmonid producers. Humboldt Bay is the most important aquatic habitat in the immediate area. The Bay area is relatively undeveloped but many agencies and private groups are interested in its developmental possibilities.

Studies of the Pacific herring have facilitated the management of commercial herring fisheries along the northeast Pacific Coast. When herring move into shallow inshore waters to spawn they become vulnerable to gill nets and haul nets. Fishery managers must know the size of the spawning stock in order to regulate the commercial harvest. Humboldt Bay has supported a bait and commercial herring fishery for several years, but no effort has been made to estimate stock size, which in turn could be used for fixing harvest quotas. Herring spawn in Humboldt Bay during December through March. Size of spawning stock, estimated from egg deposition, was 372 tons for the 1974-75 winter and 241 tons for the 1975-76 winter. Adult spawners were 2 to 11 years old, but ages II and III accounted for 57% of the estimated stock. Most spawning occurred in north Humboldt Bay even though eelgrass, the preferred spawning substrate, was less dense there than in south bay. North bay receives more fresh water than south bay, and because low-saline water stimulates spawning, this difference could account for the greater utilization of north bay.

Colorado. — Studies of the bottom sediments of Twin Lakes, Colorado, have indicated that a dramatic change in the microscopic plant life in the upper lake occurred with the onset of extensive mining developments on the watershed and increased human settlement in the area about 100 years ago. Changes in the plant community of the upper lake are still reflected in its sediments as it continues to act as a nutrient trap on the two-lake system.

Studies of populations of lake trout and opossum shrimp before completion and operation of the Mt. Elbert pumped-storage hydroelectric generating plant at Twin Lakes indicated that both species may undergo entrainment and heavy mortality during plant operation. Increased turbulence in the lake, resulting from operation of the plant, is likely to stir up loosely compacted bottom sediments and increase turbidity, thereby disrupting the currently well-established opossum shrimp-lake trout food chain.

Snake River cutthroat trout tended to segregate themselves from other trout species in small lakes. They exhibited differences in food habits, growth, survival, spatial distribution, and angling vulner-

ability. These observations suggest that the Snake River cutthroat trout can improve fishing quality by filling an otherwise unoccupied niche in small lakes.

Georgia. — Three small trout streams (Dick's, Tuckaluge, and the Chattahoochee) in north Georgia were poisoned by the State Fish and Game Division in 1970 to remove reproducing populations of rainbow and brown trout. These streams were later restocked with brook trout from headwater streams of adjacent drainages. During this study, April 1975 to April 1976, brook trout in each of the three streams grew very slowly. Total tissue growth was 0.32, 0.36, and 0.72 g of fish per square meter of water per year for Dick's, Tuckaluge, and the Chattahoochee, respectively. The Chattahoochee has significantly better trout habitat (more rubble, boulders, and riffles) than the other two streams, which most likely explains its higher productivity. These data suggest that to maintain quality fishing, anglers should take only small numbers of fish from these streams.

Bluegills were exposed to various combinations of toxaphene and methyl parathion in a static system and in a specially designed flow-through system. There was evidence of a synergistic effect of the two insecticides in tests of acute exposure. In tests of chronic exposure, high concentrations of methyl parathion (268 ppb) caused some bone deformities. There was no evidence that either insecticide or any combination of the insecticides affected growth.

Fish kills have been observed in ponds adjacent to fields sprayed with toxaphene and methyl parathion. Three days after one of these kills was reported, the concentrations of toxaphene and methyl parathion in the water were both about 6 ppb (roughly twice the concentration of toxaphene that killed fish in our laboratory studies).

Hawaii. — Streams, Hawaii's most abundant type of inland water environment, have been seriously degraded by socioeconomic growth. One of several stream-oriented studies is a statewide inventory, the first part of a three-phase project to determine effects of channelization on native fauna. Among the five largest islands, 330 perennial streams were tallied. Oahu, the most populated island, has the lowest abundance of native stream animals, and more than half of its 54 streams have significant channel alterations. Artificial channels cause elevated water temperatures, which — together with changes in food and shelter — favor the proliferation of exotic fishes like guppies and swordtails.



Opae kalaole (*Atya bisulcata*) is one of the most abundant native Hawaiian stream animals. This small (<5 cm long) shrimp prefers precipitous streams where it filter-feeds on seston particles in swift current by means of five bristles at the tips of its legs. The Hawaiian name means "spineless shrimp." *Hawaii Cooperative Fishery Research Unit photo.*



Chaetodon miliaris, an endemic yellow-and-black butterflyfish, is common on shallow Hawaiian reefs where it is collected extensively for the aquarium trade. Its abundance, fecundity, and broad habitat requirements suggest that this species is not presently in danger of exploitation. *Hawaii Cooperative Fishery Research Unit photo.*

Four Unit studies dealt with the biology and taxonomy of unique native aquatic invertebrates. Opae kalaole, a small endemic stream shrimp often netted for food and bait, heretofore has been classified as two species in different genera. Laboratory breeding trials and examination of 1,255 specimens from 15 streams indicated that the two shrimps are a single dimorphic species properly identified as *Atya bisulcata*. Favorable development of larvae in saline water and ecological data from streams demonstrated that *Atya* is diadromous; genetic uniformity throughout the archipelago is maintained by marine dispersal of larvae.

Research on anchialine pools at Cape Kinau, Maui, concluded with an evaluation of their aquatic plant communities. Representing an unusual type of aquatic ecosystem, these rocky coastal pools consist of brackish groundwater in geologically recent lavas and are connected to the ocean only through subterranean interstices. They are noted for peculiar shrimp and mollusk fauna. Four types of vegetational communities were identified: three were crusts and mats of filamentous algae dominated by *Lyngbya* and *Scytonema*; the fourth, widgeon grass with associated algae, occurred only in pools with sediment.

Concern over the exploitation of reef fishes by collectors for the aquarium industry prompted study of the biology of an endemic butterflyfish, *Chaetodon miliaris*. The fish was found to be ubiquitous, highly fecund (100,000 eggs per female), and omnivorous, with a predilection for

zooplankton. These factors and the known presence of stable populations in various types of reef habitat suggest that the species is not in immediate danger of overexploitation.

Idaho. — Effects of coarse granitic sediment on abundance, distribution, growth, and behavior of juvenile salmonids and abundance of aquatic insect drift in the central Idaho Batholith were assessed by adding sediment to artificial and natural stream channels. Densities of juvenile steelhead and cutthroat trout and chinook salmon in artificial stream channels decreased as sediment was increased. The density of insect drift was not affected by the addition of sediment to riffles in artificial streams, but Diptera increased in relative abundance. Addition of sediment reduced fish densities by causing a loss of cover and pool volume, but insect abundance was not significantly changed. In the natural streams, fish density correlated best with cover and density of insect drift whereas density of insect drift correlated best with riffle size and percentage of sediment in riffles.

Effects of closure to angling on cutthroat trout populations in the St. Joe River, Idaho, and its tributaries were assessed by evaluating species composition and the abundance and movements of cutthroat trout in closed tributaries and in tributaries open to angling. Closure to angling resulted in larger numbers of juvenile cutthroat trout and of those of catchable size because survival rate increased, whereas streams open to angling showed no significant change in abundance of



A bank stabilization structure. Even at low flow the structure, although not aesthetically beautiful, provides a scour hole at its base for fish shelter. Similar structures of rock are preferred from a fishery standpoint. *Photo by R. V. Bulkley.*



Metal and wood jetties used to protect bridge abutment on the Des Moines River, Iowa. Structure provides a scour hole and cover for fish even at low flow. Rock is superior as a construction material because it provides substrate for invertebrate production. *Photo by R. V. Bulkley.*

trout. Most cutthroat trout in tributaries retained limited home ranges and remained in their natal streams. Of more than 6,200 salmonids tagged in tributaries, 688 cutthroat trout were recovered, 610 of them in the tributary in which they were tagged. Tributaries also contained populations of migratory cutthroat trout. Progeny of the migratory stock remained in streams for 1 or 2 years before migrating. Because most of the migratory cutthroat trout we observed were in the lower sections of the tributaries, the increased abundance resulting from closure to angling presumably increased the number that entered the St. Joe River. Cutthroat trout also increased in abundance in upper sections of the closed streams but few of these trout migrated to the St. Joe River. Tributaries play an important role in the production of cutthroat trout for the trout fishery in the St. Joe River. Management alternatives — including bag limits, size limits, shortened angling seasons, and periodic stream closures — could be used to increase the stock of migratory fish and to improve the fishery for resident cutthroat trout in tributaries.

Iowa. — Studies conducted from 1973 to 1976 under five subprojects resulted in six reports providing information on channelization and its effects on stream life. Channelization of natural waterways has been an integral part of drainage and flood-control projects in Iowa since the late 1800's. Over 1,000 miles, but probably less than 3,000 miles, of streams large enough to support year-round fish populations have been lost in Iowa through stream channelization. Channelized streams vary in quality of habitat; some continue to degrade, but others contain fish populations similar in abundance and composition to those in natural streams.

Although the sinuosity index (horizontal straightness of the stream bed) correctly identifies



Rock jetties installed to protect a bridge provide shelter for fish on the Skunk River, Iowa, even at low-flow periods as shown here. In many streams with silt bottoms, these structures provide the major source of hard substrate for production of certain fish-food organisms. *Photo by R. V. Bulkley.*

previously channelized sections of streams, it does not accurately reflect the density of invertebrate drift nor fish abundance. Riffle pools caused by trees or snags can partly replace pools lost when stream beds are straightened. In streams with rocky substrate, fish abundance may be better related to stream gradient. Oxbows cut off from the main channel gradually fill with sediment and contain fewer species and numbers of fishes.

Structures for stream-bank protection that extended far enough into the stream channel to produce permanent scour holes encouraged fish use by providing cover and fish-food substrate.

Louisiana. — Seventeen research projects were undertaken within the general subject "Limnological Survey of the Atchafalaya Basin." This survey was designed to yield data for use in environmental assessment of flood-control projects in overflow habitats. Subprogram subjects included Inland Fisheries, Coastal Anadromous Fisheries, Habitat

Preservation, Stream Alteration, and Wetland Inventory. Mathematical models were developed that relate variation in abundance of key micro- and macro-zooplankton to aquatic habitat types and their respective physicochemical characteristics. The degree and direction of habitat succession in the lower Basin is now estimable, as are seasonal variations in water quality and the biota characteristic of phytoplankton, zooplankton, benthic, and fish communities in the various habitats. Our final report should prove useful in developing a plan for flood control that will protect the Basin's fish and wildlife resources.

Many fishes, as well as shrimp and crabs, spawn in the Gulf of Mexico. Later, the young use coastal marshes as "nurseries," but there is little information on the timing of their return to the Gulf. Therefore, we installed a trap on a marsh outlet to study emigration of the juvenile Atlantic croaker, an economically important fish. Catches conclusively demonstrated a continual "bleeding off" of the large juveniles from nursery to the Gulf. This observation contradicts some statements in the scientific literature (based on circumstantial evidence) that young-of-the-year leave the nursery as a group. Evidence of several population "turnovers" per year indicates that these coastal marshes are even more important to the maintenance of flourishing populations of marine fish than previously realized.

Maine. — Overwinter survival of fin-clipped and unmarked brook trout was evaluated in a reclaimed pond. Ten thousand fall fingerlings were divided into 20 treatment groups, marked by single or by multiple fin excisions, and stocked in October 1974. Analysis of returns from creel and trap-net sampling in April and May 1975 indicated that: (1) survival of unmarked, unanesthetized trout was significantly higher than that of marked fish, (2) survival of trout with multiple fin excisions was lower than that of fish with single fin excisions, (3) removal of the adipose fin was least detrimental to survival, and (4) removal of a pectoral fin was no more damaging to the fish than removal of a ventral fin. Spring recovery indicated equal vulnerability among the treatment groups to both sampling methods. Overwinter survival was low for all groups. This study indicates that care should be taken when management recommendations are made on the basis of survival rates estimated from fin-clipped brook trout.

A search of the literature revealed that sterility in fish could be induced with irradiation from X rays or radioactive isotopes. Generally, irradiation

caused side effects and sterility was temporary. Chemosterilants and high dosages of hormones disrupt reproductive function, but fertility returns after the withdrawal of treatment.

In a study of hormonal mechanisms controlling reproduction in fish, corticosteroids caused breakdown of ovarian membranes and connective tissue and neurohypophysial hormones produced contraction of ovarian smooth muscle in the guppy. Live-bearers and oviparous fish thus appear to have similar hormonal control of the reproductive process.

Massachusetts. — Most of our present knowledge of insect communities in North American streams has been incidentally acquired during fish food studies, despite the economic importance of stream insects in sustaining fish populations. Research was conducted along a 13-km woodland stream in western Massachusetts to determine diversity and emergence patterns of aquatic insects, drift distances of caddis fly larvae, and productivity of the insect community living on stones. After 2 years of extensive sampling of adults, 45 species of stone flies, 50 species of mayflies, and 120 species of caddis flies were collected from the stream. Comparing these collections with collections of immatures indicates that stream insect communities are more diverse than benthic sampling indicates. The microhabitats of uncommon and rare species are usually overlooked during routine stream sampling.

Marking of caddis fly larval cases with acrylic pigment and subcutaneous fish tags showed considerable downstream displacement of larvae. Over a 5-week period, most larvae drifted 0.4 to 0.7 km downstream from their release site; a few drifted as far as 1.5 km. High streamflow after a rainstorm dramatically increased the rate and distance of downstream displacement. Upstream flight of egg-bearing females appeared to compensate for this larval drift.

Estimates of the productivity of stone-inhabiting fauna ranged from 3.9 to 4.3 g/m² (dry weight) for two consecutive years. Mayflies were by far the most important secondary producers in the community. Algae and detritus-feeding insects contributed 88% of the productivity and carnivorous species, 12%. Low insect productivity in conjunction with high faunal diversity is probably typical of oligotrophic streams throughout the United States.

Missouri. — Excessive growth of submerged aquatic plants adversely affects recreational pursuits and fish production in many ponds and small impoundments. The effect of grass carp on

the growth of aquatic plants, on water quality, and on the production of glass shrimp, fathead minnows, and bluegills was evaluated in a series of 14 small ponds. The reduction of aquatic plants by grass carp reduced the problem of oxygen depletion, prevented adverse changes in pH and alkalinity, increased reproductive success of bluegills, and had no detrimental effect on production of fathead minnows and glass shrimp. Biological control appears to offer economic and ecological advantages over chemical control in some impoundments.

The redear sunfish was evaluated in ponds, where it was substituted for the bluegill, and in small impoundments as an additional species with largemouth bass, bluegills, and channel catfish. Missouri is an extension of the natural range of the redear sunfish, which is essentially a southern species. A mild January in central Missouri can enhance the survival of the young in ponds, and a strong year-class can in turn improve survival of young bass and growth of adult bass. However, mild winters and strong year-classes of redear sunfish are uncommon at this latitude. Nevertheless, this species is a valuable addition to the fish community in impoundments with favorable habitat.

The structure and dynamics of bass populations were evaluated in 38 ponds in the central States. The analyses indicate that poor reproduction is usually associated with a relatively low density of adults. Fishing quality was unsatisfactory in most of the ponds because there were relatively few bass longer than 30 cm (12 inches). A model for balanced populations indicates that for the length-frequency distribution of the bass stock — all bass larger than 20 cm (8 inches) — 45 to 65% should be longer than 30 cm. This balance may best be achieved by a length limit that protects all bass 30 to 40 cm (12 to 16 inches) long. The threefold intent of this regulation is to permit the harvest of surplus young bass, to allow the catch and release of bass of quality size, and to increase the harvest of large bass. The logic behind the regulation is to protect these important predators for the 25% of their possible life-span when they are most likely to gain weight. A balanced distribution has been achieved on the first lake where this regulation was applied.

Montana. — Stream morphology and game fish populations of the St. Regis River were studied in 1973-75 to determine the effects of the channelization during highway and railroad construction. Population estimates were made by electrofishing methods in stream sections that were unaltered,

recently altered, recently altered but with "mitigating" structures added, or altered several years ago. Each study section was mapped. Mitigating structures (jetties and rock clusters) provided fish habitat comparable to that in unaltered sections. Fish populations in new channels stabilized within about 1 year. Populations in "old" altered sections (with no mitigations) failed to recover the levels in unaltered sections. For aesthetic reasons, fishermen preferred unaltered or partly altered sections to those that had been channelized. The number of pools per stream section, as measured by pool-riffle periodicity, provided the closest correlation to changes in trout populations.

The fishery of Hyalite Reservoir was known to be substantial but was unmeasured. A partial creel census was conducted during the summers of 1974 and 1975 to estimate the yield of this fishery. Of the estimated 3,419 fish taken from the reservoir during the 2 years, about 90% were cutthroat trout. About 72% of the harvested cutthroat trout were hatchery fish, and 28% were wild. In 1975, only 22 wild fish and no hatchery fish were taken in the spawning run of cutthroat trout, and no cutthroat trout fry moved from the spawning stream into the reservoir. As a result of this study, 20,000 cutthroat trout fry from a wild strain have been introduced into the spawning stream in an attempt to establish a new naturally reproducing population.

Increasing demands for water will cause future alterations in the flows and water quality of Montana rivers. During 1974 and 1975, aquatic insects and water quality were studied at six riffles over a 300-km reach of the Musselshell River to obtain useful information before alterations occurred. *Choroterpes*, *Baetis*, Simuliidae, and *Hydropsyche* made up 80% of the organisms taken on modified artificial substrates. Dissolved oxygen, pH, temperature, conductivity, turbidity, calcium and total hardness, and chloride and sulfate levels at each station were recorded. Changes in aquatic insect communities and water quality, caused by future alterations of the river, can be assessed by reference to these data.

New York. — Waterborne commerce of the United States exceeds 1.5 billion tons per year. The rapid filling of our harbors and navigation channels with alluvial sand, silt, and clay necessitates dredging 300 million cubic yards of sediment each year. Sediments dredged from many areas are contaminated with heavy metals, pesticides, petroleum wastes, and other pollutants, and the resuspension and distribution of these sediments



Dorsal and lateral views of larval creek chubsuckers, total length about 7.5 mm. Accurate identification of fish larvae is necessary for analysis of the effects of power plants on the environment. Photo by L. Fuiman.

has caused much concern. The goal of a study conducted by the New York Cooperative Fishery Research Unit was to prepare a comprehensive review of the widely scattered literature on the physical, chemical, and biological effects of dredging and spoil disposal in estuaries and to identify alternative methods of spoil disposal. Over 500 scientific and technical articles were reviewed.

Alterations of circulation patterns and uncontrolled redistribution of sediments were the most important physical effects of dredging and open-water spoil disposal. Better understanding of erosion processes and mechanisms of sediment transport is needed before predictive modeling can be developed.

Remobilization of contaminants appeared to be the most important chemical effect of dredging and spoil disposal. Such factors and processes as the sediment's clay fraction and organic content, oxidation-reduction potential, pH, bacterial flora, sulfur cycles, and iron cycles are known to influence remobilization of contaminants; however, no predictive models have been developed.

Direct burial, habitat destruction, and contaminant uptake, accumulation, and recycling were the most critical biological problems associated with dredging and spoil disposal. Careful timing of dredging and spoil disposal plus construction of diked spoil marshes and islands or transport of spoils to inland sites such as abandoned mines or landfill areas appear to be the best alternatives available at this time.

During the past 2 years biologists with the New

York Unit have greatly extended the period during which largemouth bass spawn. As a result, they had newly hatched bass available for study throughout the summer. Bass were removed from ponds shortly before the onset of spawning in mid-May, when water temperatures were 17°-18° C (62°-64° F), and were held in tanks under moderately crowded conditions. A strong flow of creek water at temperatures of 15°-22° C (59°-72° F) was maintained in each tank. When bass were then transferred to ponds with temperatures of about 24° C (75° F), spawning occurred. Transfers were conducted throughout the summer; the last successful spawning occurred in early September. Besides extending the time available for research on the early life history of bass, this technique provides greater flexibility in fish culture by distributing production over a longer period. In addition, the availability of small bass over a longer season may be important for the stocking of fishing waters where natural reproduction has failed.

North Carolina. — Intensive studies of the physical, chemical, and biological characteristics of an unaltered and an altered wooded swamp stream in northeastern North Carolina demonstrated substantial differences between the systems. Dissolved oxygen, for example, was relatively high in the channelized stream throughout the year, whereas low concentrations occurred in the nonchannelized stream in late summer and early winter. The species of fish in the two systems also differed. There were numerous swamp fish, herring, and fliers in the unchannelized stream but none in the channelized stream, and the several species of cyprinids that were found occurred only in the channelized area.

In other studies, ultrasonic tracking of adult fish of several species in the vicinity of the intake structure of a nuclear power plant on the lower Cape Fear River did not produce evidence that the fish were attracted to the structure. Phylogenetic studies of North American ictalurids by karological and DNA techniques substantiated some of the conclusions of previous workers. Studies of swimming performances of juvenile spot, pinfish, and striped mullet demonstrated that sustained swimming time, time until exhaustion, and maximum swimming speed are increased by lower water velocities and higher temperatures.

Ohio. — Whirling disease of trout, caused by the protozoan *Myxosoma cerebralis*, has spread rapidly over the United States since the mid-1950's and can become critical where young fish are concentrated in large numbers, as in hatcheries.



Typical northern largemouth bass (above) and Florida largemouth bass (below) from a thermally enriched reservoir in Oklahoma. Oklahoma Cooperative Fishery Research Unit photo.

Fish can carry the spores without showing the classic symptoms of whirling disease, and a secondary method of detection in fish-holding facilities to prevent introduction of the disease into natural waters is desirable. The objective of this study was to establish simple bioassay procedures for detection of the disease in holding facilities, to determine spore concentrations necessary for positive detection, and to study the effects of temperature, increased exposure time, and extraction technique on infectivity. Infection was noted in fish exposed to concentrations as low as 8,581 spores per liter of water, but the method was not foolproof in fish exposed to concentrations as great as 139,744 spores per liter. Spores from fish carcasses were more infective than extracted spores in bioassay, and incubation times up to 240 days were required to maximize detection capability. The long incubation periods preclude widespread use of bioassay to detect the presence of *Myxosoma cerebralis* in fish-holding facilities.

Oklahoma. — Study of a sparse population of largemouth bass in a 3,300-acre reservoir indicated that differences in 1st-year growth, abundance, and production of several year classes were due largely to differences in water levels. Survival rates during the 1st year were higher than most comparable rates reported for denser populations of largemouth bass.

A nuisance growth of pondweeds was almost completely removed from a large pond to determine the effect of the removal on the growth of

stunted bluegills. Removal of the plants resulted in fewer species of fish-food organisms through the loss of macroinvertebrates associated with plants. Increases in populations of several species that consumed detritus, however, resulted in greater consumption of food (by weight) by bluegills. As a consequence, the condition of the bluegills improved, but changes in rate of growth were only minor.

Possible effects of artificial destratification of small reservoirs on depth distribution and growth of fishes are still under investigation. To date, catches in gill nets have shown that black bullheads are more tolerant of anoxic conditions than are freshwater drum and white crappies, and that gizzard shad and channel catfish generally live in areas of the lake not strongly influenced by thermal and oxygen stratification. However, vertical distribution of all species was affected to some degree by reductions in oxygen. The most pronounced effect of artificial mixing on fish was the creation of an earlier autumnal partial circulation that allowed the fish to move to deeper water.

The growth and survival of Florida and northern largemouth bass were compared in a reservoir that receives heated effluent and therefore may be suitable habitat for the Florida subspecies. Marked populations were stocked in 1974 and 1975 and were later sampled at seasonal intervals. Growth and survival were not significantly different except that overwinter survival of Florida bass was lower, especially during one severe winter. The distribution of the two subspecies differed according to water temperature, which suggests that in reservoirs located where winters are relatively mild, the introduction of Florida bass may be advantageous because they occupy habitat unused by northern bass.

Oregon. — Epizootics of bacteria-caused kidney disease have resulted in high mortalities of trout and salmon in hatcheries. Levels of antibodies for kidney disease in coho salmon at Big Creek Hatchery, Oregon, were higher in individuals with one particular blood protein-type (transferrin) than in fish with other types of transferrin. Because transferrin-type is determined genetically, we initiated a study to see whether fish with various genotypes of transferrin differed in their resistance to kidney disease. Coho salmon of known transferrin-type were infected with the disease. Mortalities were monitored, and it was found that resistance to kidney disease can be correlated with genotype. Treating the fish with various levels of

iron did not alter the mortality rates for the various transferrin genotypes. However, results of the use of radioactive iron as a tracer suggested that infected fish increase their rate of iron storage. Coho salmon infected with kidney disease exhibit alterations in various blood chemistry characteristics throughout the progression of the disease. Consequently, coho salmon can be selectively bred for resistance to kidney disease, although environmental factors may nullify any resultant benefits.

Introduction of artificially propagated steelhead trout into natural stream systems may influence resident wild populations. It is not known, however, whether there are genetic differences in growth rate or survival among offspring from matings of hatchery x hatchery, wild x wild, or hatchery x wild fish. Four natural streams and a hatchery pond in Oregon were each stocked with eggs or unfed fry from each of these three matings. A genetically determined biochemical marker was used so that fish from each type of mating could be distinguished. Hatchery fish mated with hatchery fish had the best survival and growth in the pond, whereas fish with two wild parents had the best survival in streams. Hatchery fish mated with wild fish had the best growth in natural waters. In conclusion, hatchery fish are genetically different from wild fish and, if the two interbreed, the stock recruitment of wild populations can be adversely affected.

The red-band trout, an undescribed species native to many small isolated streams in south-eastern Oregon, provides wild populations for recreational fishing. Data collected on the population size, age composition, growth, biomass, recruitment, fertility, and habitat of red-band trout in Threemile Creek indicated that production was extremely high. A terminal irrigation reservoir on the creek increased the total production of the system by at least 12 times. Terminal reservoirs might be considered management tools for improving trout populations in small streams; they provide larger trout than the streams would ordinarily produce.

Pennsylvania. — Diurnal activity of wild adult smallmouth bass was studied during summer, fall, and winter. The bass spent most of their time (79-91%) in activities unrelated to movement. Almost all activity was restricted to areas where current velocity was low to moderate. Interactions with other smallmouth bass accounted for less than 1% of their time. Social organization in the population was based on a fairly stable order of dominance and on individual "exclusive use spaces" that apparently

moved with the individual, changed shape, expanded or contracted, and were defended with varying intensity. Most feeding behavior was observed late in the day and probably continued into the night, after observations had ceased. Smallmouth bass apparently used several strategies to minimize expenditure of energy.

Many attractive trout streams in the Appalachian Mountains are unproductive because of their acidity and low level of nutrients. Such streams might be managed for production of native trout or stocking of catchable trout by the use of limestone water treatment and other techniques. Although often intensified by boggy areas, the acidity appears to originate from rainfall and the geochemistry of the watersheds, coupled with the low buffering capacity of the water. A prototype limestone bed is being evaluated along with basic studies of water chemistry.

Brine shrimp have been proposed as a versatile and convenient starter food for "cool water" fish, especially northern pike, in hatcheries. Extensive tests led to guidelines for reliable production of brine shrimp on a routine basis and a large scale, without complex and expensive facilities. A solution of 0.5% rock salt in hard water proved most suitable as a medium. Different brands and ages of eggs varied greatly in hatchability.

South Dakota. — Studies are being conducted to determine the life history of paddlefish in a section of the Missouri River in South Dakota. The study area is a 93-km stretch of free-flowing river extending downstream from the lowermost dam on the Missouri River. Habitat is similar to that available to paddlefish in this region before it was influenced by man. Bank stabilization and river channelization have altered the river downstream from this area, and installation of bank stabilization structures will soon alter habitat in the study area.

Paddlefish were visually observed from late spring to early fall and were located during the remainder of the year by netting and snag fishing. From late spring to early fall paddlefish were mainly found downstream from submerged sandbars, where the crests of the bars were 0.1 to 0.8 m below the surface, the river depth was 1.5 to 4.5 m, and the current velocity was 0 to 0.3 m/s. Nearly all large concentrations of paddlefish during this period were downstream from sandbars or in slow- or dead-water areas adjacent to a channel. Concentrations of paddlefish from late fall to early spring were primarily in slow- or dead-water areas more than 3 m deep and adjacent to the main channel of the river.



Faculty and students from the Pennsylvania Cooperative Fishery Research Unit marking 8,000 rainbow trout to be stocked and studied in Stone Valley Lake. *Photo by R. L. Butler.*

Food of paddlefish was nearly 100% zooplankton. Feeding was clearly heaviest in spring and fall and nearly ceased from about July to September. Paddlefish appeared to feed continuously when levels of food consumption were high. Nonfood items composed 37 to 78% by volume of the total stomach contents.

Measurement of length from the eye to the fork in the tail was determined to be more reliable in paddlefish than either total or fork length. Sexual dimorphism in both length and weight was determined to be statistically significant for fish in age groups II to XXII. Few mature females were

observed. More than 35% of all paddlefish captured bore scars that apparently resulted from collisions with boats, injuries inflicted by snag hooks, or other damaging encounters. Of all fish tagged and recaptured, 67% traveled downstream and 26% upstream; 7% were caught near the site of release. Of the fish that traveled downstream, three had moved 680 to 780 km in 3 to 5 months.

Tennessee. — Three of the studies conducted on the fisheries of Center Hill Reservoir were designed to model the fish population of the reservoir by the use of a computer, and the information thus obtained will be incorporated into an overall model

of the fish population. Such a model should help fishery biologists manage fish populations in reservoirs.

Some types of artificial shelters for fish have been successful in some reservoirs but not in others. A 3-year study was conducted in two reservoirs to evaluate "stake-bed" shelters. They increased fishing success for crappies in a reservoir with a fairly stable water level but not in one with a fluctuating water level.

A survey was made of the fishes of the Cumberland River in the area of a proposed nuclear power plant. Other surveys will be made during the construction of the plant and after it is in operation to determine whether the fish population is affected by it.

Utah. — Biochemical and genetic studies of fish populations were emphasized. Two lactate dehydrogenase isoenzymes of rainbow trout were examined kinetically. They were found to differ in reaction mechanism, binding constants, pH inhibition, and other factors. In another study, rainbow and cutthroat trout were found to differ in the number of electrophoretic hemoglobin fractions. The major fractions are being isolated and described. The data from these two studies will be useful to fish culturists in producing fish that more readily adapt to the environment.

Studies of rare and endangered fish species of the Upper Colorado River are completed. Information is now available on the life history, movements, habitat needs, and ecological requirements of the Colorado squawfish and humpback sucker. These data will be useful for planning future water-development projects that may affect the remaining habitat of these endemic fish.

The effects of channelization on the aquatic life of an intermountain river are being studied. The age composition, standing crop, and production of the principal fish (brown trout and mountain whitefish) and invertebrate populations in altered and unaltered sections of the Logan River were determined and compared.

The Utah chub is the focus of studies dealing with the manipulation of undesirable fish populations. The chub frequently competes with western game fish for food and habitat. Preliminary studies are providing data on the biology and life history of the chub in a typical Utah reservoir. The action of fish toxicants on the chub is also under investigation.

Virginia. — Nuisance populations of an exotic aquatic plant, *Egeria densa*, hampered use of the 1,093-ha Chickahominy Reservoir, southeast Virginia, for recreation and potable water. A

mixture of diquat dibromide and potassium endothall was applied at 2.83 liters of each chemical per 0.4 surface ha. There were no measurable changes in water quality after treatment, except for a general decrease in dissolved oxygen. No fish kills were observed. Oxygen consumption indicated that 24 to 76% of the biomass of rooted plants was decomposed through oxidation in areas of heavy growth. Both herbicides had declined to low levels in the water 3 days after treatment and were undetectable 16 days after treatment. Anglers refrained from fishing while the treatment was in progress and believed the project increased fishing and boating enjoyment.

In a second recently completed project, artificial reefs were evaluated in 8,100-ha Smith Mountain Reservoir. Over 7,000 scrap tires and 400 Christmas trees were used to form four types of structures. Scuba surveys indicated that many species were seasonally associated with the reef structures. Various sunfish species used the reefs for shelter during the summer. Fewer fish were observed around the reefs during the colder months (December-February). Catfish deposited their eggs inside the tires, and gizzard shad and sunfish were observed grazing directly on the periphyton attached to reef substrate. In shelter-deficient nonflowing waters these artificial reefs effectively concentrated warmwater game and forage fish.

Washington. — One of the recently completed projects dealt with methods for controlling the eye fluke, *Diplostomum spathaceum*, which affects trout in many Washington lakes. Salmonid species differed widely in resistance to the eye fluke: rainbow trout were the most resistant, followed by cutthroat trout, brook trout, and coho salmon. Larger fish were able to carry more eye flukes than were smaller fish of the same species. The survival time of rainbow trout and brook trout exposed to a controlled number of eye fluke cercariae was increased from twofold to more than threefold by immunization with a crude eye fluke extract.

Another project was directed toward solving management problems affecting the kokanee salmon fishery in Lake Stevens, Washington. Streams entering and leaving the lake were surveyed regularly for spawning activity during the fall of 1975.

Percentage survival of deposited eggs was estimated from counts of spawning kokanee and from trapping of out-migrant fry the next spring. Spawning areas in need of habitat improvement or special protection were identified. Although extensive spawning occurred in the lake outlet,



Tending traps designed to capture kokanee fry migrating downstream from Lake Stevens, Washington. *Photo by J. L. Congleton.*

there was no upstream migration of newly emerged fry back into the lake the next spring. Electro-phoretic analysis of fry collected from the outlet and from tributary streams is being performed to determine whether outlet spawners were derived from a stock normally spawning in inlet streams. If so, the fry could be genetically predisposed toward downstream migration after emergence.

Data were collected over a 1-year cycle on physical, chemical, and biological conditions in the spawning tributaries and in the lake. This information will be used to support efforts to counter the effects of progressive watershed urbanization and to maintain a viable kokanee fishery.

Wisconsin. — Although angling for smallmouth bass in lakes in the north-central United States has been popular — sometimes even famous — for many years, the bass populations have not been studied intensively. A 2-year study of the smallmouth bass population and fishery in 850-acre Clear Lake, Wisconsin, was conducted to obtain information for use in fish management. Fish were caught in fyke nets, tagged, and released in spring and early summer, and anglers were interviewed in a creel survey during the fishing season.

Annual mortality in a smallmouth bass population is typically 50 to 65%, but in Clear Lake the annual rate was 77%, most of it due to fishing. Anglers

annually harvested 42% of the bass over 9 inches long. Creel fish were small (average length, 8.7 inches), and the catch rate of six bass for 100 hours of angling was not unusual for the species. We estimated that anglers caught 5 to 9 smallmouth bass per acre from a population of 22 bass per acre.

We estimated that a limit of 12 to 14 inches in minimum length would cause the total weight of harvested bass to increase by 14%. In addition, the average size of fish in the population would increase, as would the catch and release rate. As a result of the study, a regulation limiting minimum length to 12 inches for smallmouth bass will be initiated next year on an experimental basis.

COOPERATIVE WILDLIFE RESEARCH UNITS

Alabama. — A field study of the effects on wildlife of pine seed treated with endrin-arasan was conducted in southern Alabama. A 55-acre area was seeded with pine seed treated with 0.5% active endrin and 8.0% arasan, which has been employed to protect the seed from damage by insects, birds, and rodents. Fourteen captured bobwhites fitted with transmitters were released on the area after treatment. Seven of the instrumented bobwhites were found dead within 40 days, and radio contact



Taming of carnivores through food handouts by workers on the Trans-Alaska Pipeline has led to wildlife nuisance problems and has altered patterns of wildlife mortality. This wolf is being offered food in the interests of photography by a pipeline worker at Isabell Pass camp. *Photo by D. R. Klein.*

with the others was lost. Also, five bobwhites from one covey were dead within 3 days after release on the treated area. Many birds and mammals collected or found dead on the treated area contained endrin residues.

Data on habitat use and seasonal movement were obtained from 105 eastern wild turkeys instrumented with radio transmitters and from non-instrumented turkeys on four study areas in Alabama and one in Kentucky. The turkeys preferred a diversity of habitat types in their ranges and often made seasonal movements to meet their needs. Their movements and seasonal ranges indicated the importance of openings to turkeys. Hens moved farther in the spring than gobblers because of their special needs for nesting and brood-rearing habitat. Twelve to 25% of spring and summer habitat should consist of well-dispersed clearings in order to lessen the distance of spring dispersal of hens seeking open country to nest and raise poults.

Alaska. — Aerial and ground counts of caribou in the vicinity of the Trans-Alaska Pipeline and the adjacent haul road on Alaska's North Slope show that females and calves use the areas close to the pipeline-road complex much less than the more distant areas. Behavioral observations indicate that cows with calves are more sensitive to highway traffic than bulls, which, during the peak of the insect season seek out elevated gravel pads, roads,

and airstrips to obtain relief from insects, thus causing problems for highway traffic and landing aircraft. In general, carnivores and scavengers have been attracted to the construction camps and pipeline work pad, where food handouts by



Studies of productivity of the dusky Canada goose on the Copper River Delta by personnel of the Alaska Cooperative Wildlife Research Unit have assessed the effects of the 1964 earthquake on the welfare of the goose population. *Photo by D. R. Klein.*



Inspecting Harris' hawk nest in saguaro. *Photo by L. K. Sowls.*

workers and improper garbage disposal have resulted in taming of wolves, bears, and arctic and red foxes. Highway mortality of foxes is high, apparently because they frequent the roads in anticipation of food handouts. Several bears that became nuisances and threatened human life around the construction camps had to be shot. The Alaska Board of Game has now imposed regulations making it illegal to feed animals throughout the State. Food wastes have also attracted many ravens, glaucous gulls, and ground squirrels to the camp areas.

Studies of nesting ecology and productivity of the dusky Canada goose on Alaska's Copper River Delta, the sole breeding area for this race of goose, show that elevation of the delta by approximately 3 m as a result of the 1964 earthquake has had pronounced effects on the nesting habitat of the geese. Although elevation of the land allowed mammalian predators freer access to the nesting areas, avian predation lessened as the invasion of shrubs and forbs along slough banks and into the now drier sedge meadows created more nesting cover. Raising of the vegetated portion of the delta



Removing young Harris' hawk from nest for banding. *Photo by L. K. Sowls.*



Banding young Harris' hawk for return to nest. *Photo by L. K. Sowls.*

well above high tide levels has halted destruction of nests by storm-caused flood tides, which periodically have caused catastrophic losses in the past. The delta is still undergoing change, with shrubs and trees invading the open meadows much more rapidly than new marshlands are developing at the periphery of the delta. Consequently, over a period of time there may be a substantial reduction in available nesting habitat.

Arizona. — In 1975 a controversy between falconers and protectionists over raptor regulations

in Arizona demonstrated the need for more information on these species. That year, a study on the ecology and status of Harris' hawk was initiated. In an intensive search for nesting Harris' hawks, 134 active nest sites were found since January 1976, all within Maricopa, Pima, and Pinal counties. Harris' hawks are asynchronous nesters and have a long nesting season. Egg-laying dates ranged from January to September. Forty of the 157 nesting attempts at the 134 nest sites were failures. The following are examples of the productivity observed: Three clutches were laid by one female between January and June; the second clutch failed but five young were produced from the first and third clutches combined. Two other females each laid two clutches and each female produced seven young. Over 200 young were produced from the nests under observation.

Study of bobcats in Arizona has been neglected until recently, when the value of predators became recognized by many people. In 1975 a study of the populations and food habits of bobcats was undertaken on the Three Bar Wildlife Area near Lake Roosevelt, Arizona. During 8 trap-nights, bobcats were captured, marked, and released, or were observed, in an area of about 29 km². An estimated minimum density for the study area was 0.28 bobcat/km², indicating a relatively high density. Attempts to attract bobcats to scent stations and visual attractant stations, where tracks could be counted, were unsuccessful. Rodents and lagomorphs were the most frequent foods (66.5 and 37.5%) identified in 176 scats collected. Deer and javelina remains were identified in 2.8% and less than 1% of the scats, respectively. The frequency of rodent and lagomorph remains in the scats was not correlated with the numbers of prey censused, suggesting that these bobcats were selective in their feeding habits.

Colorado. — An effort to estimate the number of mountain lions in a specified geographic area of Colorado was undertaken in 1974. The study site selected for the first season (winter 1974-75) lay between Canon City and Cripple Creek and covered approximately 900 km² (350 square miles). Two lions were marked and released on this area. Study of the 37 sets of tracks recorded on the area led to a population estimate of 15-25 lions, or 1 lion per 36-60 km² (14-23 square miles). The second segment of the study was carried out on a 1,950-km² (750-square-mile) area between Canon City and Salida. Three of the 17 lions marked and released on this expanded study area were later treed (a total of 20 captures). An analysis of captures and of the



Canadian Wildlife Service Biologist selects an egg from a whooping crane nest at Wood Buffalo National Park. One egg from each two-egg whooping crane nest was transplanted to the nest of sandhill crane foster-parents at Grays Lake, Idaho. Photo by E. Bizeau.

135 sets of lion tracks recorded during this second season supported an estimate of 35-65 lions, or 1 lion per 30-56 km² (12-21 square miles). It was concluded that the mountain lion population in Colorado is probably larger than was formerly estimated and that it probably is not in danger of being overharvested.

Idaho. — The whooping crane, with its one tenuous migration route from the breeding area in Wood Buffalo National Park in the Northwest Territories of Canada to the line wintering spot at Aransas National Wildlife Refuge in Texas, has long teetered on the brink of extinction. In 1975 an experiment was launched to field-test the feasibility of employing greater sandhill cranes as foster-parents to hatch whooping crane eggs, rear the chicks to flight stage, take them south as family groups to winter in New Mexico, and return the young whoopers the next spring. The goal is establishment of a new population of whooping cranes that will nest in southeastern Idaho and winter in New Mexico.

On May 29, 1975, 14 whooping crane eggs were transplanted from Wood Buffalo National Park to Grays Lake National Wildlife Refuge in Idaho. Nine eggs hatched. Four chicks survived and migrated with their foster-parents to the wintering area in New Mexico. All four families remained intact throughout the winter and returned on

schedule to the San Luis Valley in south-central Colorado, the major stopping point in the spring and fall migration of the Rocky Mountain population of sandhill cranes. In April the whooper yearlings were left in the San Luis Valley to fend for themselves as the foster-parents returned to Grays Lake to begin a new nesting cycle. The orphaned whoopers slowly made their way north. None of the yearlings returned to their natal marsh at Grays Lake in the summer of 1976. Three of the four were monitored at widely scattered summering locales in southeastern Utah, southeastern Idaho, and south-central Montana; the fourth yearling was not located. The first year of the project has demonstrated that whooper eggs can be successfully transplanted into sandhill crane nests and that the chicks are readily accepted and reared by the foster-parents. Parental care was excellent, and the whooper chicks readily adapted to the sandhill crane diet and living pattern.

Iowa. — Organization, movements, distribution, and abundance of three herds of elk at Wind Cave National Park, South Dakota, were studied to permit more efficient management of elk through herd reduction by trapping. Elk were marked with ear flags, colored collars, or radio collars. Twenty bulls were captured by baiting a trap with salt, six calves by hand, and six cows by immobilization with syringe darts containing succinylcholine

chloride. Use of a helicopter was most effective for delivering syringe darts to free-ranging cows.

Marked elk were observed 713 times and located 113 times by telemetry. Three relatively discrete herds of cows and calves — herd sizes of 170, 90, and 40 — were identified in the 44-square-mile park, occupying ranges of 8, 10, and 4.5 square miles, respectively. Bulls also seemed divided into three or more discrete herds.

Elk were most readily observed during hours closest to sunrise and sunset. They generally fed in grassland areas and bedded in wooded areas. They preferred easterly or southerly slopes during most of the year and usually avoided steep slopes in all seasons. Aerial counts of elk in the Park probably underestimated the population.

Reduction is not necessary for one of the three herds; this herd crosses the Park fence and spends time in the Black Hills National Forest, where it is subject to hunting. Definition of the ranges of the other two herds will indicate where traps can best be placed to reduce herd size. Knowledge of the seasonal distribution of elk within the Park helps Park managers to determine range use and to guide visitors through the Park.

Louisiana. — Habitat evaluation is a major research responsibility. One study involving the bobwhite was conducted from September 1974 through February 1976 to establish a population index in Louisiana and to observe related land use practices. Ten call index routes, each 30.5 km long and with 20 stops, were sampled throughout the State, and land use at each stop was recorded. Call index values ranged from 4.05 to 0.55 and peaked in June at an average of 1.57. Seventeen land-use associations in seven categories were recorded: row crops, small grains, pasture, residential, edge, woodland, and marsh. Four associations, partly or entirely woodland and pasture, supported 64.4% of the bobwhites along the routes. During the fall, flush counts along the survey routes yielded only three coveys, and these were on the routes with the highest call index.

The Breeding Bird Survey was analyzed to determine whether it could be used as an index to bobwhite abundance. It was not significantly related to hunting success or land-use and could not be used as an index of bobwhite numbers in Louisiana. An analysis of bobwhite wings from hunter-killed bobwhites in 1974-75 and 1975-76 indicated good reproduction, with 85 and 82% young, respectively. The cock to hen ratio was 120:100 each season. Hunting pressure was not a limiting factor on bobwhites in Louisiana. The



Radio collars, such as the one on this cow elk, were used to study herd movements and distribution of elk in Wind Cave National Park by the Iowa Cooperative Wildlife Research Unit. The study resulted in information that will aid Park personnel in herd management. *Photo by K. L. Varland.*



Helicopter used in drive-trap procedure for banding Canada geese on the west coast of Hudson Bay. Photo by R. A. Malecki.

apparent surplus of bobwhites surviving after the hunting season suggests that the number of bobwhites in the State should be increasing — but it is remaining stable. Current land use does not provide sufficient winter cover to allow bobwhite numbers to increase.

Maine. — During the past 2 years measurements were made of Maine coyotes for taxonomic and management purposes. Mean weights of adult males and females were, respectively, 15.9 and 14.5 kg; mean total lengths were 1,233 and 1,193 mm, and skull lengths were 205 and 195 mm. Pelage was of four general phases, being similar to those described for northeastern coyotes and eastern wolves and distinct from that of dogs. Seventy adult skulls from Maine and 44 from Quebec were analyzed taxonomically with the use of linear discriminant function. Of the specimens from Maine, 67 were identified as skulls of eastern coyotes and 3 as skulls of dogs. Maine coyotes seem to represent a wild hybridized form that became progressively purer as it moved eastward. The results of computerized study agree with earlier conclusions based on ocular examination and subjective judgment.

Physiology of breeding female American eiders in Maine was studied from 1973 to 1975. Seasonal changes in body and organ weights were used to evaluate the relative status of nutrient reserves.

Total carcass fat and protein levels, and blood characteristics, were also studied. Females established large nutrient reserves prior to egg laying and then virtually stopped feeding during laying and incubation. Body weights decreased 32%; the loss was especially noticeable in weights of pectoral muscles. Failure to establish sufficient nutrient reserves may often limit renesting ability and probably also adversely affects nesting success of young adults through proportionally more nest desertions. The semistarvation of nesting females is an important stress factor that may, at times, be associated with heavy losses from epidemic diseases or parasites. Avian cholera was an important periodic cause of mortality among incubating Maine eiders.

Massachusetts. — An ecological study of the fisher, using radiotelemetry, was conducted on the White National Forest in New Hampshire. Fishers are highly mobile, traveling throughout most of their home range (1,922 ha) within almost any 2-week interval. Adult males traveled the greatest distances, adult females the smallest, and subadults of both sexes moved intermediate distances. Neither home range size nor sharing of home areas was related to age or sex. Fishers are very active diurnally; during summer daylight hours they were active approximately 85% of the time. Fishers preferred wetland association (predominantly



Exploring critical habitat of the grizzly bear in the Lincoln-Sagegoat Wilderness Area. Photo by K. L. Craighead.

alder) and mixed softwood-hardwood forest types, and avoided open areas and pure hardwood stands. Food items most commonly found in the stomachs of fishers were mice, carrion, squirrels, birds, shrews, and fruit. Annual layers in the cementum of teeth were accurate indicators of age.

Missouri. — The major breeding ground of the eastern prairie population of Canada geese is in Manitoba, between latitude 56° and 60° N and longitude 92° and 99° W, an area of about 59,700 square miles. Band recoveries indicate that geese nesting north of this area belong to the tallgrass prairie population and those to the east to the Mississippi Valley population. Breeding populations surveyed within the major breeding area of the eastern prairie population increased nearly 40% between 1972 and 1975. Goose sightings from slow-flying aircraft must be multiplied by about 1.4 to reconcile them with ground-truth data obtained by observation from helicopters. Forty-four to 68% of estimated numbers of breeding pairs, 1972-75, were in tundra habitat south of Churchill, Manitoba, which made up less than 8% of the area surveyed.

Research on the call behavior of mourning doves confirmed the findings of previous studies that pairing is the most important factor affecting

calling. Unmated wild males called at significantly higher rates and had greater probability of being heard during 3-minute intervals than mated males. Although unmated males called at significantly higher rates when at least one other dove was calling, the rate did not increase as the number of calling doves increased. Other types of measurements showed that call rates of individual doves are not markedly affected by population densities, as asserted by earlier authors.

Montana. — The Endangered Species Act prohibits Federal agencies from jeopardizing threatened or endangered species by disturbing or destroying critical habitat. Critical habitat for most species has not been defined or delineated. Conventional data-gathering techniques, combined with electronic scanning and digital data recording from satellites, were used in the Lincoln-Sagegoat Wilderness Area in Montana to define and analyze critical habitat for the grizzly bear. Radio monitoring and tracking of free-roaming animals, using thematic satellite imagery maps to record movement, distribution, habitat preferences, and behavior, are now feasible and will open new vistas in wildlife research and management.

Scats collected throughout the year on the

National Bison Range indicated that voles were the most important single food of coyotes. Native ungulates (especially fawns), insects, seeds, berries, and cattle (presumably carrion) were seasonally important. Although coyote predation may be a major cause of fawn mortality, increased numbers of coyotes did not always result in a decrease in the number of fawns per doe. Individual coyotes adept at finding and killing fawns could be more dangerous than a large number of less proficient coyotes. Proximity of coyote dens correlated with mortality of pronghorn fawns in the three herds on the Range.

New York. — Recent studies indicate that recreational opportunities in New York State are rapidly disappearing as landowners react against misuse of their properties by hunters, operators of snowmobiles, and other recreationists. A joint effort between the New York Department of Environmental Conservation and the Unit was undertaken in 1972-73 to examine levels of posting against trespass, reasons for posting, and related landowner attitudes in 28 of the same rural New York towns studied in 1963. The results of the new study were noteworthy. In 1963, 5.5 million acres of private land were posted; by early 1973, 9.2 million acres were posted, a 65% increase in the last 10 years. Moreover, if the trend evident from 1963 to 1973 were continued to 1993, virtually all private land in the State would be closed to public access.

If the escalating conflict between landowners and recreationists is to be eased, comprehensive programs must be undertaken to educate the snowmobile operator, the hunter, and other users of private lands to change their behavior and image. Recreationists and private landowners will both need the protection of mutually advantageous management programs such as New York's Fish and Wildlife Management Act, which encourages and assists private landowners in opening their lands to the hunting and fishing public. If these programs are to be effective, cooperation from both public agencies and industry will be required.

Ohio. — Leg muscles and livers from road-killed white-tailed deer and cottontail rabbits collected during 1971-75 in west-central Ohio were analyzed for cadmium, lead, and mercury content. Concentrations of these elements were significantly higher in livers than in muscles for both species. Rabbit livers contained significantly higher levels than did deer livers. Concentrations in body tissues were generally well below guidelines recommended by the U.S. Food and Drug Administration and consequently posed no threat to human consumers.

Lead levels in vegetation collected near highways were directly related to volume of traffic and were inversely correlated with distance from the highways. Variations in cadmium levels in plants appeared related to the cadmium content of the soil and not to distance of the plants from highways. Mercury levels differed between vegetative types and areas and seasons of collection, but no specific pattern was noted.

The only known method for accurately aging adult Canada geese is by banding at a known age. Decalcified and stained 14-micron sections of all wing and leg bones from 19 known-age (1-7 years) geese from Ohio were examined to determine the feasibility of aging geese by counting annuli in bone periosteum. Periosteal annuli were present in all bones examined, but the number was not consistent for the various sections of the bones examined. Birds 1-2 and 5-7 years old were consistently over- and under-aged, respectively. This technique was concluded to be infeasible for aging Canada geese.

Oklahoma. — Sixteen skull and tooth measurements taken on each of 138 wild *Canis* collected during 1975-76 were compared with those from museum specimens to detect temporal changes in *Canis* taxonomy. Records of depredation experienced by the cattle industry were compared with average *Canis* body size and extent of coyote x dog hybridization within Oklahoma. Size characteristics of *Canis* appear stable except to the southeast, where red wolf x coyote genetic influence is declining. Losses of cattle appear to be positively related to the larger size of canids in the southern and southeastern counties. No correlation was found between the prevalence of coyote x dog hybridization and predation on cattle.

A project was initiated to determine the causes of fawn mortality in white-tailed deer on the Wichita Mountains National Wildlife Refuge and on the Fort Sill Military Reservation. Thirty-five fawns, 1 to 28 days old, were captured and fitted with radio transmitters. Their average annual mortality proved to be 88%. Predation by coyotes and bobcats caused 97% of the observed mortality. Eighty-three percent of the mortality occurred by the time fawns were 60 days old. Thus, predators killed a substantial proportion of the fawn population even though deer densities were low (8 deer/km²).

Oregon. — The Oregon and Idaho Cooperative Wildlife Research Units, in cooperation with the University of Washington, completed in 2 years the first systematic inventory of wildlife and wildlife habitat resources along the Columbia and Snake



Rocket net being fired to capture band-tailed pigeons. Research on band-tailed pigeons, conducted in Oregon, is directed toward determination of survival rates and age structure of this popular Pacific Coast game bird. *Photo by M. F. Passmore.*

ivers. Special attention was directed toward identifying the impact of fluctuating pool levels to accommodate “power peaking” — the coordinated release of water by the many dams in the system to meet changing energy demands on a daily, weekly, and seasonal basis. Breeding waterfowl and aquatic furbearers, often concentrated in relatively short stretches of river immediately below some dams, are especially vulnerable to the disturbances of power peaking. The Great Basin Canada goose may serve as an indicator species for the negative impact of power peaking, as nesting, feeding, and brooding areas are all adversely affected.

Pennsylvania. — As part of a comprehensive study of black bears, blood samples were collected from 44 immobilized bears captured in northeastern Pennsylvania between October 1972 and November 1973 (one, two, three, and four samples were collected from 31, 7, 3, and 3 individuals, respectively, a total of 66 samples). The samples provided information on 23 blood chemistry and hematology parameters. The resulting data were statistically analyzed to establish normal blood values and to determine their relationship to sex, age, or season.

Our data indicate that female bears tend to be anemic and to have lower levels of calcium in the blood. This tendency toward anemia may be caused by the demands of pregnancy and lactation,

because females nurse their cubs for 2 or more months during winter dormancy. They do not eat during this period, and thus minerals lost during late pregnancy and lactation cannot be replaced. Cubs and yearlings also tend to be anemic and may have a higher turnover of red blood cells than adults. Advancing age is accompanied by an increase in blood cholesterol, suggesting that food habits or the utilization of foods may alter with age. Increases in total protein and globulin with age may indicate increased antibody production in older bears. Seasonal differences in certain red blood cell indices and in glucose suggest heightened activity of the blood-producing organs and increased ingestion of high-energy foods during the predenning period. Some individuals demonstrate abnormal blood profiles, which are attributable to various possible causes including dehydration, stress, tissue damage, renal dysfunction, and disease.

South Dakota. — The flock of giant Canada geese in northeastern South Dakota numbered about 2,000 birds in 1973. The South Dakota Department of Game, Fish and Parks has a management goal of 5,000 birds for that flock. Although public sentiment favored this goal, some farmers opposed it because waterfowl depredations on small grain crops would increase. It appeared that attitudes of farmers might be the major factor



Three ferruginous hawk nestlings at their nest on top of a large butte in northwestern South Dakota. The nest, approximately 2 m in height, has been used for a number of years. Photo by C. Blair.

prohibiting management from reaching the goal of 5,000 geese.

Four hundred farmers in northeastern South Dakota were interviewed in 1974 and 1975 to measure their attitudes toward expansion of the flock. Eighty-six percent of the interviewed farmers favored the expansion. Only 6% of the farmers complained about the geese, even though 23% of them had crops damaged by geese. Percentage occurrence of complaints and of crop damage was influenced by distance of goose concentration areas from farms. Farmers whose land was adjacent to goose concentration areas had a lower tolerance for geese than those farther away but retained relatively positive attitudes toward the geese and flock expansion. Farmers' complaints about crop damage concerned geese eating small grains, trampling small-grain swaths, grazing shoots of small grains in spring, and attracting trespassing hunters.

Productivity of the goose flock was also measured and was comparable to success reported for flocks of giant Canada geese in other parts of the country. Desertion was the most common cause of nest failure. Predation and flooding did not appear to be major limiting factors in nest success. Nest success appeared adequate to support or expand the flock, indicating that the goal of 5,000 geese is probably realistic.

Utah. — A 2-year greenhouse investigation at Utah State University to determine the effects of fertilizers on *Potamogeton pectinatus*, *Ruppia maritima*, and *Chara* has been completed. A completely randomized block design with six treatments was used: control; 28, 56, 112 kg N/ha; 56 kg N and 56 kg P/ha; and 56 metric tons sewage

sludge/ha. Analysis of variance and covariance, and regression techniques were employed to determine growth response in terms of production, height, and dry weight of shoots, reproduction, and tissue nutrients. Nitrogen fertilization improved the growth of *Potamogeton* and *Ruppia*. Phosphate fertilization improved only the growth of *Potamogeton*. Large amounts of nitrogen and phosphate fertilizer inhibited the growth of *Chara*. Nitrogen yields from tissue analysis increased linearly with added treatment nitrogen in *Potamogeton* and *Ruppia*. Phosphorus in the sewage sludge was believed to have increased plant height and dry weight but also produced heavy growth of algae. Soil and water analyses showed losses of ammonia, nitrate, and phosphorus by the end of the experiments. Recommendations were made for study of fertilization in a spring-fed marsh.

Virginia. — Data on the effects of stream channelization on riparian wildlife populations and their habitats along three streams were collected from January 1975 through July 1976. The streams studied were channelized 2, 5, and 9 years prior to the investigation. The study was designed to measure the recovery of wildlife populations at the successional stages that developed after channelization. The relative composition of vegetation and the relative abundance of small mammals and birds were determined for each study site. Populations of mammals were estimated each year by snap-trapping and livetrapping 1.1 ha on each study site. Bird abundance was estimated twice each year by winter transect counts and breeding bird inventories. Indices of species diversity for vegetation, small mammals, and birds increased from the youngest to the oldest channelized stream. Channelization appeared to affect wintering populations less than breeding populations of birds. Bird diversity and density were significantly lower along the younger channelized streams, where vegetative complexity had been more recently reduced by removal of trees and shrubs. During the breeding season, parulids appeared most affected by stream alteration. Relative changes in diversity values of small mammal and breeding bird species between the 3- and 6-year-old channelized streams indicated that small mammal populations recovered more quickly than breeding bird populations. The small difference found in mammal and breeding bird diversities between the 10-year-old channelized stream and the unchannelized stream strongly suggested that 10 years after channelization, riparian small mammal and breeding bird

populations were approaching those of the unchannelized (control) stream. Both breeding bird and small mammal populations recovered as the complexity of the riparian vegetation increased. Information gained from this study may be used to predict the impact of channelization and may thus contribute to rational land management by State and Federal agencies and private landowners.

Wisconsin. — The coot is one of the most important migratory game birds in Wisconsin, but few data on coot populations are presently available. The need for data will probably escalate as harvests and harvest rates of coots increase. In 1974-76, approximately 5,000 coots were banded in southeastern Wisconsin. Band recoveries to date suggest that most of the harvest in Wisconsin occurs in the southeastern portion of the State and along the Mississippi River. Coots from Wisconsin apparently winter along the Gulf of Mexico and the Atlantic Coast.

Deer cause damage to apple orchards in many States, and Wisconsin is one of nine States that reimburses orchardists for apple losses. Approximately 77% of the apple growers reported damage by deer. Browsing of buds was the type of damage most frequently reported. The physical damage to mature apple trees can now be adequately measured, but the relationship between browsing and subsequent fruit production is unknown. In 1975, studies to define this relationship and to develop indices to deer damage in orchards were begun. Preliminary work suggests a correlation between deer damage and pellet group counts associated with individual trees. Feeding trials with penned deer indicate that deer prefer terminal apple buds to lateral or axillary buds. Simulated browsing experiments and measurements of damage and subsequent production in three orchards are still under way.

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Appendix

DIRECTORY OF RESEARCH FACILITIES AND PERSONNEL (as of June 15, 1977)

Central Offices

(Mailing Address: U.S. Department of the Interior,
Fish and Wildlife Service, Washington, D.C. 20240)

Division of Wildlife Research

Richard N. Smith, Acting Chief

Division of Fishery Research

Dr. James A. McCann, Chief

Division of Habitat Preservation

Nelson B. Kverno, Chief

Major Research Facilities

Atlantic Salmon Investigations

Dr. Robert E. Lennon, Chief
319 Murray Hall
University of Maine
Orono, ME 04473

Denver Wildlife Research Center

Dr. Charles M. Loveless, Director
Building 16, Federal Center
Denver, CO 80225

Eastern Fish Disease Laboratory

Dr. Kenneth Wolf, Director
R.D. 3, Box 41
Kearneysville, WV 25430

Editorial Office

William R. Dryer, Technical Editor
U.S. Fish and Wildlife Service
Aylesworth Hall, CSU
Fort Collins, CO 80523

Fish Control Laboratory

Dr. Fred P. Meyer, Director
P.O. Box 818
La Crosse, WI 54601

Fish Farming Experimental Station

Dr. Harry K. Dupree, Director
P.O. Box 860
Stuttgart, AR 72160

Fish Genetics Laboratory

Dr. Raymond C. Simon, Director
Beulah, WY 82712

Fish-Pesticide Research Laboratory

Dr. Richard A. Schoettger, Director
Route 1
Columbia, MO 65201

Great Lakes Fishery Laboratory

Dr. Joseph H. Kutkuhn, Director
1451 Green Road
Ann Arbor, MI 48105

Migratory Bird and Habitat Research Laboratory

Dr. Fant W. Martin, Director
U.S. Fish and Wildlife Service
Laurel, MD 20811

National Fish and Wildlife Health Laboratory

Dr. Milton Friend, Director
6101 Mineral Point Road
Madison, WI 53706

National Fish and Wildlife Laboratory

Dr. Clyde J. Jones, Director
U.S. National Museum
10th and Constitution Avenue, NW
Washington, D.C. 20560

National Reservoir Research Program

Robert M. Jenkins, Director
113 South East Street
Fayetteville, AR 72701

Northern Prairie Wildlife Research Center

Dr. W. Reid Goforth, Director
Box 1747

Jamestown, ND 58401

Patuxent Wildlife Research Center

Dr. Lucille F. Stickel, Director
U.S. Fish and Wildlife Service
Laurel, MD 20811

Pyramid Lake Project

Earl A. Pyle, Leader
U.S. Fish and Wildlife Service
63 Keystone Avenue, Room 207
Reno, NV 89503

Southeastern Fish Cultural Laboratory

Dr. Blake F. Grant, Director
Marion, AL 36756

Tunison Laboratory of Fish Nutrition

Dr. Gary L. Rumsey, Director
Cortland, NY 13045

Western Fish Disease Laboratory

Thomas Parisot, Director
Building 204, Naval Support Activity
Seattle, WA 98115

Cooperative Fishery Research Units

Auburn Univ., Auburn, AL 36830
Dr. John S. Ramsey, Leader
Univ. of Arizona, Tucson, AZ 85721
Dr. Jerry C. Tash, Leader
Humboldt State Univ., Arcata, CA 95521
Dr. Roger A. Barnhart, Leader
Colorado State Univ., Fort Collins, CO 80521
Dr. William J. McConnell, Leader
Univ. of Georgia, Athens, GA 30601
Dr. Robert E. Reinert, Leader
Univ. of Hawaii, Honolulu, HI 96822
Dr. John A. Maciolek, Leader
Univ. of Idaho, Moscow, ID 83843
Dr. Theodore C. Bjornn, Leader
Iowa State Univ., Ames, IA 50010
Dr. Robert J. Muncy, Leader
Louisiana State Univ., Baton Rouge, LA 70803
Dr. Charles F. Bryan, Leader
Univ. of Maine at Orono, Orono, ME 04473
Dr. Richard W. Hatch, Leader
Univ. of Massachusetts, Amherst, MA 01002
Dr. Roger J. Reed, Leader
Univ. of Missouri, Columbia, MO 65201
Dr. Richard O. Anderson, Leader
Montana State Univ., Bozeman, MT 59715
Dr. Richard W. Gregory, Leader
Cornell Univ., Ithaca, NY 14850
Dr. John G. Nickum, Acting Leader
North Carolina State Univ., Raleigh, NC 27607
Dr. Melvin T. Huish, Leader
Ohio State Univ., Columbus, OH 43210
Dr. Bernard L. Griswold, Leader
Oklahoma State Univ., Stillwater, OK 74074
Dr. O. Eugene Maughan, Leader
Oregon State Univ., Corvallis, OR 97331

Dr. Carl B. Schreck, Asst., Leader

Pennsylvania State Univ., University Park, PA 16802

Dr. Robert L. Butler, Leader

South Dakota State Univ., Brookings, SD 57006

Dr. Donald C. Hales, Leader

Tennessee Technological Univ., Cookeville, TN 38501

Dr. R. Don Estes, Leader

Utah State Univ., Logan, UT 84321

Dr. Richard S. Wydoski, Leader

Virginia Polytechnic Institute and State Univ.,
Blacksburg, VA 24061

Dr. Garland B. Pardue, Leader

Univ. of Washington, Seattle, WA 98105

Dr. Richard R. Whitney, Leader

Univ. of Wisconsin, Stevens Point, WI 54481

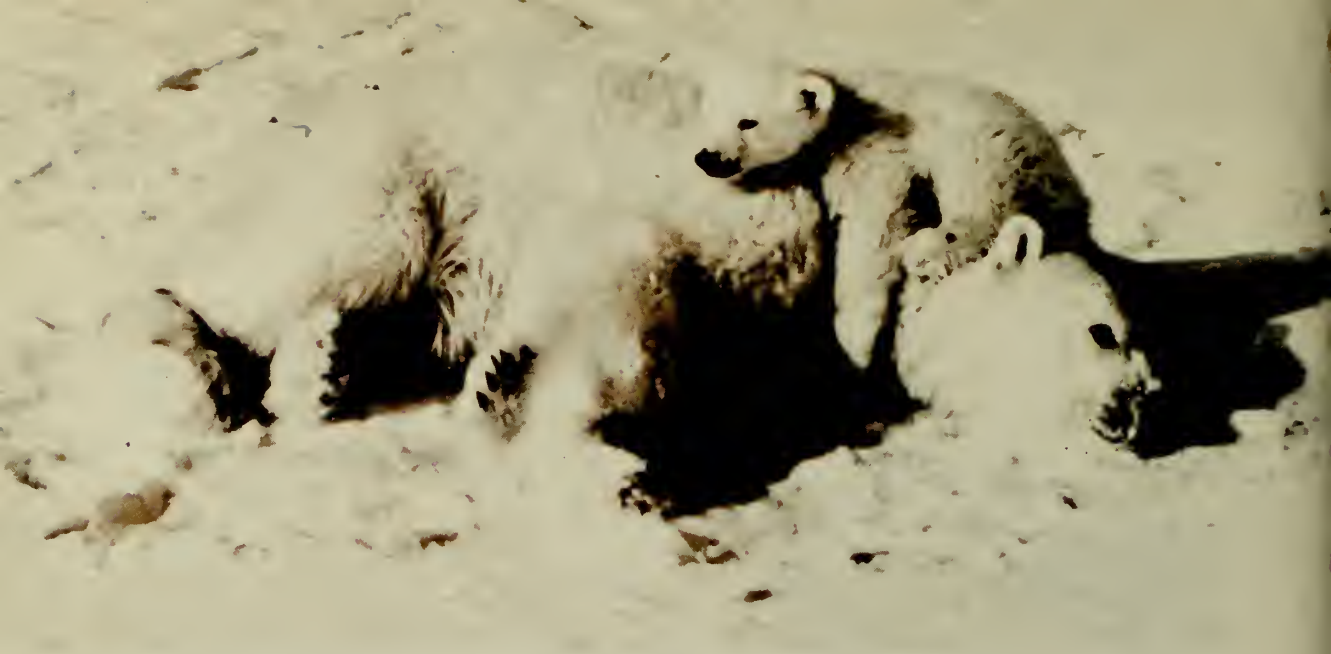
Dr. Daniel W. Coble, Leader

Cooperative Wildlife Research Units

Auburn Univ., Auburn, AL 36830
Dr. Daniel W. Speake, Leader
Univ. of Alaska, Fairbanks, AK 99701
Dr. David R. Klein, Leader
Univ. of Arizona, Tucson, AZ 85721
Dr. Lyle K. Sowls, Leader
Colorado State Univ., Fort Collins, CO 80523
Dr. Kenneth R. Russell, Leader
Univ. of Idaho, Moscow, ID 83843
Dr. Maurice G. Hornocker, Leader
Iowa State Univ., Ames, IA 50010
Dr. Robert B. Dahlgren, Leader
Louisiana State Univ., Baton Rouge, LA 70803
John D. Newsom, Leader
Univ. of Maine at Orono, Orono, ME 04473
Howard L. Mendall, Leader
Univ. of Massachusetts, Amherst, MA 01002
Dr. Wendell E. Dodge, Leader
Univ. of Missouri, Columbia, MO 65201
Dr. Thomas S. Baskett, Leader
Univ. of Montana, Missoula, MT 59801
Dr. John Craighead, Leader
Cornell Univ., Ithaca, NY 14853
Dr. Milo E. Richmond, Leader
Ohio State Univ., Columbus, OH 43210
Dr. Theodore A. Bookhout, Leader
Oklahoma State Univ., Stillwater, OK 74074
Dr. Paul A. Vohs, Jr., Leader
Oregon State Univ., Corvallis, OR 97331
Dr. E. Charles Meslow, Leader
Pennsylvania State Univ., University Park, PA 16802
Dr. James S. Lindzey, Leader
South Dakota State Univ., Brookings, SD 57006
Dr. Raymond L. Linder, Leader
Utah State Univ., Logan, UT 84322
Dr. David R. Anderson, Leader
Virginia Polytechnic Institute and State Univ.,
Blacksburg, VA 24061
Dr. Burd S. McGinnes, Leader
Univ. of Wisconsin, Madison, WI 53706
Dr. Donald H. Rusch, Leader



Sharp-tailed grouse (above) and sage grouse (below) occupy areas that may be disturbed by future strip mining for coal in the West. Sage grouse return to traditional areas for breeding each year. *Photo by D. E. Biggins.*



The U.S. Fish and Wildlife Service is conducting research on polar bears in Alaska. Animals are marked to obtain information on movements and populations. This female bear (estimated to weigh 350 pounds) and cub (15 pounds) were captured in April 1976 and fitted with numbered ear tags for individual identification. This program will provide a basis for evaluating the status of polar bears in Alaska. *Photo by A. L. Kolz.*

Male polar bear approximately 40 miles north of Barrow, Alaska, being instrumented with a 164-megahertz, mortality-sensing transmitter. The bear was estimated to weigh about 900 pounds. *Photo by A. L. Kolz.*

